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ABSTRACT

This volume contains 48 papers and 9 abstracts/research notes. Titles include: "Alternative constructs and cognitive development: commonalities, divergences and possibilities for evidence"; "Discipline knowledge and confidence to teach science: self-perceptions of primary teacher education students"; "Teacher beliefs about learning and teaching in primary science and technology"; "Physics teachers' action-research experiences with a teaching module on 'Force'"; "Learning in interactive science centres"; "Progression in learning science"; "Students' perceptions of an innovative university laboratory program"; "An ecological perspective on research with computers in science education"; "Student perceptions of technology and implications for an empowering curriculum"; "Classroom behaviour settings for science: what can pre-service teachers achieve?"; "The importance of selected textbook features to science teachers"; "Development of an instrument for measuring attitudes or early childhood educators towards science"; "Combining issues of 'girl-suited' science teaching, STS and constructivism in a physics textbook"; "What has happened to intuition in science education?"; "Reconstructing the interactive science pedagogy: experiences of beginning teachers implementing the interactive science pedagogy"; "Introducing technology education to young children: a design, make and appraise approach"; "The applications of science to technology"; "The historical anecdote as a 'caricature': a case study"; "Risk-taking and teachers' professional development: the case of satellite remote sensing in science education"; "The reluctant primary school teacher"; "Expert-novice differences in science investigation skills"; "Adult experiences of science and technology in everyday life: some educational implications"; "Improving the quality of primary science teaching through a pre-service course"; "Teaching and report writing in primary science: case studies of an intervention program"; "Professional standards for the teaching of science: an exploratory study"; "Primary science education: views from three Australian states"; "School-based assessment of practical competence in science: some issues from English experience"; "Teachers' perceptions of technology education: implications for curriculum innovation"; "Improving a playcentre science programme through action research"; "Retraining chemistry teachers in the Philippines"; "Science and technology management: designing an undergraduate course"; "Reporting to parents: science in the context of the total primary curriculum"; "Students' understanding of concepts related to evaporation"; "Becoming a science teacher: first year teachers' approaches to learning about teaching"; "Dealing with graphic output from diagram processing tasks: approaches to characterisation and analysis"; "Developing networks of grass-roots science curriculum action"; "Constructivism and empiricism: an incomplete divorce"; "Can any good come out of researching in science education and being a science teacher at the same time?"; "Learning in professional practice schools: beyond clinical experiences and teacher workshops"; "Primary pre-service teachers' pedagogical reasoning skills"; and "Pupils' understanding of combustion." (MKR)

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Research In Science Education

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1992

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Selected refereed papers from the Twenty-third Annual Conference of the Australasian Science Education Research Association, held at the University of Waikato, Hamilton, New Zealand, 10-12 July, 1992.

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EDITORIAL COMMENTS

I feel very privileged to have been the editor of this volume of RISE, because the publication provides tangible evidence of a research organisation in a flourishing state of health. The 23rd ASERA conference —the second to be held in New Zealand — attracted a large number of participants (about 120), including several from countries outside the region. An unprecedented number of papers were presented (more than 80), most of which (65) were submitted for publication; and although space pressures precluded all of these from being published, this edition of RISE contains a record number of entries (48 papers and nine abstracts/research notes). It is the first time that a RISE volume has exceeded 400 pages. Its production drew upon the efforts of a very large editorial review panel; let me express my thanks here to the reviewers for their prompt and useful comments; several authors expressed their appreciation to me for the constructive help given to them.

This issue of RISE is not merely large, but *rich:* in the quality of the research being reported and in the scope of the topics, approaches and contexts represented. Although ASERA is a regional organisation, we are attracting an ever-growing number of international participants: this edition includes contributions from researchers in England, Germany, Spain, South Africa, Hong Kong and the United States.

ASERA began life 22 years ago through the efforts of academics principally interested in secondary school science. This collection encompasses work done in play centres, in primary and secondary schools, and in undergraduate, teacher education and professional development programs. The papers also refer to work done in a wide range of fields. Eight years ago, in an editorial introduction to a collection of papers given to a UNESCO conference on science and technology education in Germany, I commented on the paucity of educational research in the field of technology education and said that perhaps, "a decade or so from now, at another symposium on these topics, this bias might be overcome." In the present volume, a fifth of the papers reflect technological themes. And finally, the collection is rich in research styles. The organisation (and this editor) has no pre-conceived views about the best way to conduct science education research. Cognitive studies, attitude studies, curriculum development and evaluation, quantitative research, historical and philosophical research, phenomenological research, papers supporting constructivism and a paper questioning constructivism: all find their place in this volume.

This is an appropriate place to pay tribute to one man, who more than any other, helped to establish ASERA and nurture its development. In 1967, Peter James Fensham, then reader in chemistry at the University of Melbourne, came to Monash University to take up his appointment as Australia's first professor of science education. His qualifications were remarkable: a double Ph.D., one in chemistry from the University of Bristol, and one in social psychology from the University of Cambridge. He proceeded to attract around him a group of staff and post-graduate students with an interest in science education. Within a couple of years of his appointment, he conceived of a national organisation which would bring science education researchers together. It was the right idea at the right time; it was a period in which there was strong government interest in science education. The federal government had funded the building of school science laboratories, and was now, in co-operation with the states, turning its attention to nationally funded curriculum projects. The million-dollar Australian Science Education Project was established in 1969, and there was fruitful co-operation between ASEP staff and science education researchers in the universities. (Two years later, the first ASERA journal would be published by ASEP.)

In May 1970, a meeting was held at Monash to discuss the possibility of establishing a professional association. (In enumerating the ASERA conferences, this meeting has always been counted as the first.) A more formal conference, held at Sydney's Macquarie University, was planned for the following year; at this second conference, papers were presented and published in Research 1971, the forerunner of this journal (which explains why the papers of the 23rd conference appear as Volume 22.) ASERA and its annual journal were established; in his preface, founding editor Dick Tisher described the future as "challenging and bright". He was right. The association has never looked back.

As the humorous and loving "roasting" given to Peter at the ASERA conference dinner in Hamilton so amply testifies, his international contributions to science education, his intellectual support to colleagues and students, and above all his character as a warm and caring human being, are all held in the highest regard. This year, 1992, marks both the 25th anniversary of his appointment to Monash and his retirement from the university. It was Dick White who formulated the now famous Law of Fenshamian Motion: if you stand on any spot on earth and wait long enough, Peter Fensham will go by. All of us hope that he will have a stimulating, enjoyable and healthy retirement, and that he will give all the members of the organisation he founded many opportunities to prove the truth of White's Law, again, and again, and again.

Paul Gardner
Editor

Monash University
December, 1992.

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GUIDELINES FOR AUTHORS FOR THE PREPARATION OF PAPERS AND DISKS FOR RESEARCH IN SCIENCE EDUCATION

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Hard copies only are required for submission to the ASERA conference organisers. Setting out can be in the same format as required for publication, or in some other format if you prefer.

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Fig. 3 A model of the learning process

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Research in Science Education, 1992, 22, 1 - 10

ALTERNATIVE CONSTRUCTS AND COGNITIVE DEVELOPMENT: COMMONALITIES, DIVERGENCES, AND POSSIBILITIES FOR EVIDENCE

Philip Adey
Kings College London

ABSTRACT

The last fifteen years of research in science education has seen the emergence, flowering, proliferation, and now perhaps slight wilting of studies of pupils' alternative constructs. Meanwhile the older, broadly Piagetian, tradition of work rooted in notions of cognitive development was attacked as being, inter alia, deterministic, concentrating on what children could not do, and getting even that wrong since children could be shown to be a lot cleverer than the cognitive developmentalists claimed.The time has perhaps now come to look at these two lines of work together to see what assumptions they share and where their paradigms, aims, and methods differ significantly. In this paper I will claim that there is far less antagonism between the two traditions than is often represented, but that nevertheless the differences are fundamental and lead to different views of the purposes and potential of science education. Possible evidence that might be adduced in support of one view at the expense of the other will be considered and exemplified with recent results of a cognitive acceleration project.

TWO TRADITIONS

Two important stories emerged from science educational research in the 1970s. One concerned the Alternative Conceptions that children held about scientific phenomena, and attempts to change these Alternative Conceptions into 'scientists' conceptions. The other was about the limits imposed on understanding of complex concepts by pupils' levels of cognitive development. Major proponents of the Alternative Conceptions story included Champagne, Klopfer, Erickson, and Novak in North America ; Osborne, Freyberg, and Gunstone and White in Australasia; and Driver and Gilbert in the UK (e.g. Osborne & Freyberg, 1985; Novak, 1987; Champagne, Gunstone & Klopfer, 1985; Driver, 1983). The Cognitive-Developmental banner was meanwhile carried in the U.S. by Karplus, Renner and Lawson; to some extent by the Australian Science Education Project in Australia, and by ourselves and the Science 5-13 project in Britain (e.g. Karplus, 1979; Lawson, 1989; Shayer & Adey, 1981).

IN COMMON

Protagonists of both schools are concerned about the ineffectiveness of much current science teaching whether it be by traditional chalk and talk methods or by activity led 'discovery' methods. The former eliminates activity by the learner which is seen as essential for effective learning, while the latter too often degenerates into practical activity for its own sake, without the cognitive activity which is the necessary basis of all learning.

Both approaches focus on what goes on in children's minds when faced with the scientists' view of phenomena. Describing the phenomena is one thing, explaining them in terms which are scientifically useful is something else entirely. Thus it is a matter of primary observation that when a rubber sucker is pressed against a smooth surface it tends to stay there, and requires some force to pull it off again but it requires considerable mental activity to comprehend, let alone to construct, an explanation for this observation in terms of the greater bombardment of particles on the outer surface of the rubber compared with the inner surface. Most importantly, both approaches rest on the belief that pupils must construct their own knowledge from experience and that knowledge cannot simply be transferred from teacher to pupil without effort on the part of the learner.

Finally amongst their commonalities both groups agree that perceptions are influenced by current beliefs. How you interpret and describe what you observe depends upon the theories you hold about that particular topic. Two scientists with different theories will "see" different things in the same event. Just how far this principle should be taken depends on one's view on the existence of objective reality. On a spectrum from extreme positivism to extreme relativism neither of the schools of thought discussed here are näively positivistic but cognitive developmentalists usually, and alternative conceivers often, accept that there is some objective reality out there but that our interpretation of that reality will be influenced by personal beliefs more or less depending on the extent to which the interpretation demands the construction of abstract models. Thus it is a matter of observation that at one standard atmosphere pressure pure water will boil at 100 °C. This I would consider as a "fact", the only interpretation of which is the ascription of a number based on an agreed scale of temperature. To account for this fact in terms of molecules of water breaking free of one another is a matter of interpretation, but it is an interpretation which is so robust in its ability to make predictions and so much more comprehensive in its explanatory power than any rival interpretation that I would accept it as the best approximation to reality that we have so far. Going to a further level of abstraction, to explain what is happening in solid, liquid, and gaseous water in terms of hydrogen bonding requires far more tenuous hypothesis building. This is the stage in the development of theories at which scientists are liable to commit their reputations and publication records to one construction of reality rather than another.

The point of this digression has been to illustrate a "relative positivist" position held, I believe, by most Cognitive Developmentalists and many Alternative Conceivers with respect to reality and its interpretation. There is however a tendency within the Alternative Conceptions movement to flirt with a far more radical relativist position. From such a position (von Glaserfeld, 1987; Latour & Woolgar, 1973) any 'fact' is a construction of the human mind and if the society of scientists were so minded they could propose an infinite number of equally valid alternative ways of imposing personal reality on to the boiling point of water. If I fail to convey the radical constructivist view accurately it is because I find it very difficult to understand.

An important consequence of even the relative constructivist point of view for the present paper is that comments made on the Alternative Conceptions position should be read in the knowledge that they are written by someone who is working in a somewhat different theoretical framework.

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...AND DIFFERENCES: SOME PRINCIPLES OF COGNITIVE DEVELOPMENT

Central to the difference between the approaches is the Cognitive Developmentalists' concentration on a central processing mechanism of the mind, seen as a gateway which controls all intellectual activity, in whatever subject domain. Furthermore, as the term "cognitive developmental" implies, it is supposed that the power of this cognitive structure develops from conception to maturity under the genetic, maturational, and experiential influences. Most Cognitive Developmentalists favour a stage-wise developmental process in which at certain ages there is a qualitative shift in the kind of problems that the mind can handle. This was the nature of the theory established by Jean Piaget through over 40 years of work with children and reflection on their responses.

An important corollary of stage-wise cognitive development is that a child who demonstrates formal operational thinking in one context is most likely to be able to do so within any context. One who fails to demonstrate formal operations on any one or two appropriate tasks is unlikely to do so on any other. In other words, cognitive development is context- independent. A deterministic inference is sometimes drawn from this position which is the crude "matching" idea: "Charlie can think only at the level of early concrete operations, so don't waste your time and his by trying to teach him abstract ideas." In other words, learning material should be tailored to make cognitive demands which are no higher than the current level of thinking of the learner. Many educators are, quite reasonably, shocked by such a negative view of the teaching and learning process which concentrates more on what children cannot do than on what they can do.

SOME PRINCIPLES OF ALTERNATIVE CONCEPTIONS

The Alternative Conceptions paradigm rests partly on Kelly's personal construct theory and partly on Ausubel's ideas of meaningful learning. From Kelly comes the idea that we must each construct knowledge for ourselves: an idea which, as outlined above, cognitive developmentalists have no difficulty in accepting. Ausubel usefully distinguished between rote learning of isolated facts, and meaningful learning in which new knowledge is linked to a framework of existing knowledge. Meaningful knowledge is seen as growing from and on existing knowledge. One consequence of this is that the movement has focussed on the child's development of knowledge and understanding within particular topics and subject domains. On this basis, they have produced an impressive catalogue of the types of misconceptions held by pupils at different ages in many and diverse topics: electric current flow, the shape of the earth, nutrition in plants, and many more.

However, since educators who concentrate on pupils' alternative conceptions tend to discount the role of the central processor there is nothing in their model which allows links to be made between a child's understanding in one area and her likely level of understanding in another. The fact that a child has difficulty explaining the stuck rubber sucker in terms of atmospheric pressure tells the educator who concentrates on alternative conceptions nothing about the same child's likely comprehension of activities about photosynthesis. This contrasts with the developmentalist position which, if it works, allows one to make good predictions of an individual's performance over a wide range of problem areas from a sampling of their performance on one or two. While the

Alternative Conceptions approach focusses on domain-specific learning processes, Cognitive Developmentalists place more emphasis on learning processes which are general across all domains.

Finally, the Alternative Conceptions model, discounting the idea of a developing central processor, seems to offer no theoretical limit to what an individual can be taught to understand. The CLISP (1987) approach to teaching and learning is based on the idea that if one takes time to expose a child's current conceptualisation, encourages her to generate testable hypotheses and weigh these hypotheses against experimental evidence, then the child will construct for herself a view of the world which is similar to that of mature scientists. No systematic limits are supposed to be set by the child's age or by the complexity of the ideas being taught. This is a lovely idea, but one that strikes me as owing more to wishful thinking than to realism. Notwithstanding the probable power of CLISP-type methods for establishing meaningful learning of concepts in some pupils, the Alternative Conceptions movement themselves have produced some striking evidence of the resistance of children's misconceptions to change (see Gauld, 1986, for a remarkable example), and others (Kuhn, Amsel & O'Loughlin, 1988) have shown that children, and even adults, do not readily correlate the evidence of experiment with their hypotheses in order to change permanently their concepts.

ANTAGONISTS? CAN EVIDENCE HELP?

If it were the case that the differences between the theoretical standpoints of the Alternative Conceptions movement and of the Cognitive Developmentalists were such that the two approaches were incompatible then workers in the two fields would necessarily be professionally antagonist to one another and a game would start of accruing "evidence" in support of one position or another. We would then fall into the classic mould of scientists recognised by radical constructivists in which every new "fact" is interpreted by each side as grist to its own mill. While I have rather more respect for evidence than do radical constructivists I do recognise that where a theoretical model is of a tentative and abstract nature then Thomas Kuhn's account of scientific progress has apparent validity. Newtonian mechanics versus relativity, particulate versus wave theories of light, or big bang versus continuous creation theories of the universe all contain examples of respectable and intelligent scientists digging themselves into defensive positions based on faith rather than a truly objective analysis of the evidence.

There are two major problems with trying to draw an analogy between these august examples and our own petty differences. The first is that the two movements, at their cores, are not incompatible. They are rather the results of emphases on different aspects of conceptual development. It follows that it would be an unfortunate disservice to education generally if antagonist positions were to be taken up and defensive lines drawn. The second problem lies in the nature of evidence, already alluded to. Some evidence will be presented below which seems, at the very least, compatible with the cognitive developmentalist position and difficult to explain without the notion of a central context- independent cognitive processor. But however strongly I felt the evidence could be interpreted in favour of one theoretical model, those who see science as only a social construct would, by the nature of their theoretical position, be unimpressed. To the extent that a group aligns itself with the radical constructivist position, to that extent do they move themselves outside the possibility of argument which calls on research evidence.

AN ACCOMMODATION?

Monk (1990, 1991) has re-analysed some key Alternative Conceptions through Cognitive-Developmentalist spectacles. He showed that it is possible to map the quality of pupils' conceptualisations, as reported by Osborne (1981, 1983), Shipstone (1984), Guesne (1985), Ramadas and Driver (1989), and others directly on to the ages at which pupils attain the stages of cognitive development found by Shayer, Küchemann and Wylam (1976) and Shayer and Wylam (1978). The fit is particularly good for the post-instruction responses, suggesting that these stages provide an upper limit to the complexity of conceptualisations attained. Monk has added to the rich and useful set of descriptions of alternative frameworks provided by Alternative Conceptions workers an explanation, which has predictive power, of how these alternative conceptions arise in terms of the children's cognitive processing capability at different ages and what are the limits within which they may be changed.

Monk is careful to point out that level of cognitive development alone cannot predict a subject's performance on a task which involves both processing power and knowledge. No matter how powerful the processor, it cannot produce a correct answer if it does not have the appropriate instruction or experience. Thus to say as Ramadas and Driver (1991) do that according to Monk's analysis Euclid must have been only at the early concrete operations stage is to ascribe a stage on the basis of a response given in the absence of adequate instruction. Had a time traveller been able to debate with Euclid the nature of light and sight, with appropriate demonstrations, Euclid would have had little difficulty understanding the concept. What Monk is claiming is that regardless of the quality or quantity of instruction a child will not gain the scientist's conceptualisation until his cognitive processing system has developed adequately.

LEARNING AND DEVELOPMENT

It is in exploring the distinction between instruction and development and the contributions of both to the development of science concepts that the respective contributions of instruction based on alternative conceptions work and intervention based on cognitive developmentalists' ideas could be seen to be encompassed in a common theoretical framework whilst the immediate goals of their work remains different. On the face of it there is not much danger of confusing learning with development. Development carries with it the idea of unfolding, of maturation, of the inevitable. Learning on the other hand is purposeful, and it may or may not happen. These differences may be expressed as a series of poles (Table 1)

There are many biological contexts in which we think of development as something which happens almost inevitably, given adequate nutrition and the absence of disease. We speak of the development of a plant from a seed and the development of an embryo from a zygote. The word 'learning' could not be applied in such cases, but is the word 'development' in the term 'cognitive development' used more than metaphorically? For many (including classical Piagetians) it is, and cognitive development is seen as closely related to the maturation of the central nervous system.

TABLE 1
LEARNING AND DEVELOPMENT

Learning tends to be ...	Development tends to be ...
Conscious: we are aware when we are learning and can choose whether or not to learn	Unconscious: it happens without our conscious effort
Multidirectional: we can learn many different sorts of things and choose in which direction to go.	Unidirectional: A given organism is only likely to develop in one way. Later and earlier stages of development can be identified.
Endless: There is no limit to the amount we can learn about any topic.	Goal directed: There are at least natural end-points to the developmental process. We recognise individuals as mature, in the sense that they will not develop further.

But even classical Piagetians call on the process of equilibration to promote development. Equilibration is the establishment of a new developmental state as a result of interaction with the environment. An event, an observation, occurs which the child cannot assimilate into her present way of understanding. A possible result is the accommodation of that way of understanding to the new observation. This accommodation is a development of the cognitive processing system. It is development in that it is unconscious and can proceed in only one direction, and it is partly under control of ontogenetic and phylogenetic release mechanisms and yet, in so far as it requires a particular type of stimulus from the environment, it can become a learning process. As soon as one accepts that the environment plays a role in the process of cognitive development the way is open for the environment to be manipulated by a parent or a teacher. If this counts as teaching, and I believe that it does, then the effect on the child must count as learning.

So we see, after all, that there is not such a sharp distinction to be made between development and learning but that they might better be seen as shading into one another along a spectrum from 'extreme' learning to 'extreme' development. Current theories of learning and development lie between these extremes, with those tending towards the Learning end emphasising the importance of efficient instruction, and those tending towards the Development end focussing rather on intervention in the developmental process.

CONTEXTUALISED OR GENERAL?

The learning-development spectrum can be mapped on to the context-dependent versus context-independent question about just how general learning can be, or just how specific it must be. The Ausubelian position that meaningful learning involves the attachment of new learning to existing knowledge about a topic holds out the promise that knowing something about a topic facilitates further learning in that topic: but how broad can 'topics' be? In particular, when does a topic become a domain with a characteristic body of semantic knowledge procedural knowledge, and what is the nature of the debate between those who say that learning is, most importantly, domain specific and those who rather emphasise the importance of thinking strategies common to all domains?

When we talk of domain general knowledge or abilities we may refer to some sort of general problem solving skills which can be applied equally to investigating ways of improving health provision and to why the washing machine has broken down. To put it like this is to make the idea seem ridiculous, which it probably is, and to explain the failure of many problem solving models to be usefully general. There is, however, another sense in which we can conceive of domain-general abilities, and that is in terms of intellectual processing power. Cognitive-developmentalists, amongst others, consider that the most important determinant in controlling learning in any domain is the general data-processing capabilities of the mind. They concede the existence of fields of knowledge and sets of procedures characteristic of different domains but claim that no amount of training or experience within a domain will lead to expertise unless a person has the fundamental intellectual infrastructure required to master the concepts and procedures of any domain of knowledge.

If indeed it proved possible to raise learning potential across all domains by an effort expended on the central processing capability of the mind then this would offer an enormously efficient use of educational time and effort. In other words, if time spent on developing general thinking skills were to be shown to produce positive effects in learning in a wide variety of domains, then this would represent a handsome pay-off for the effort expended. The evidence for such general development would be the transfer of a training effect from the domain in which it was delivered to domains of a very different nature which lasted long after the training programme.

COGNITIVE ACCELERATION

This is what we were exploring in the Cognitive Acceleration through Science Education (CASE) project. We might have taken this as a text:

> ...learning which is oriented toward developmental levels that have already been reached is ineffective from the viewpoint of a child's overall development. It does not aim for a new stage of the developmental process but rather lags behind this process. (Vygotsky, 1978, p.82)

We learnt from others' attempts that the direct teaching of the schemata of formal operations (control of variables, proportionality, probabilistic thinking and the others) was generally not successful. On the other hand there was a suggestion that some general effect could be achieved by methods which (a) provided adequate concrete scaffolding to ensure that the students were as well prepared as possible, and then (b) some sort of cognitive conflict, in which the learner finds that her or his present way of thinking about a situation no longer yields an adequate solution. A third important feature which cognitive psychologists seem to agree is necessary for the promotion of general thinking skills is metacognition, encouraging learners to think about their own reasoning and reflect on their successes and failures in solving problems. Finally, we learnt that thinking lessons isolated from curriculum content were less likely to have effects on academic achievement than those which had been bridged into the curriculum.

There are some important ways in which these features are found in the CLISP methodology for teaching science concepts. In particular, "cognitive conflict" seems a quite proper description of the feelings experienced by a CLISP pupil when, having exposed her own conceptions and designed a critical test, finds that the evidence does not accord with her original idea. The intense discussion of ideas and constructive argument for different points of view in a CLISP classroom are an important part of the metacognitive process. But there are important differences also, of perceived purpose as much as of procedure. Thus the process of exposing preconceptions which is such an important feature of the CLISP method is replaced in CASE methodology by the relatively simple concrete preparation phase. In CLISP is, as I understand it, it is the attainment of the scientific concept which is the ultimate goal, although a staging post in which the student develops an interpretation which works for her in her present requirements is also acceptable. In CASE, attainment of any particular concept is not considered as important as the cognitive process itself. It is the struggling with the problem that is important, whether or not a "right" answer is attained. The CASE aim may be described as metaconstructivism, where the entity to be constructed is not a science concept but a way of thinking.

The results of the CASE experiments have been reported elsewhere (e.g. Adey & Shayer, 1992) and here I will give only an outline. Using the four features of concrete preparation, cognitive conflict, metacognition, and bridging as guiding lights and looking to the ten schemata of formal operations (Inhelder & Piaget, 1958) to provide a context, we drafted a set of 30 activities (Adey, Shayer & Yates, 1989) for use with years 7 and 8. Teachers in eight schools tried them out over a two year period, using the activities instead of normal science lessons with experimental classes once every two weeks for two years. Control classes continued with their normal science curriculum. At the end of the intervention period experimental classes showed significant gains in levels of cognitive development compared with controls but there was no difference in their science achievement. Three years later however, when the students took their GCSE examinations, those who had previously experienced the CASE intervention scored significantly higher grades than those who had not, not only in science but also in mathematics and in English. This shows the long term far transfer described earlier as evidence for the existence of some general cognitive processor which can be positively influenced by appropriate educational experiences.

INTERVENTION AND INSTRUCTION

This experiment has been summarised here again because it provides a neat example of what we mean by intervention: intervention in the cognitive developmental process which raises the students' general intellectual ability such that they can make more efficient use of instruction in any domain. However, such intervention does not provide information. It does not, of itself, lead students to a scientist's understanding of important topics such as plant nutrition, ecological balance, and practical dynamics. A total curriculum of intervention activities would be like a diet of double cream. We need the strawberries too, we need effective instruction as well as the development of cognitive processing.

CONCLUSION

I believe that supporters of the Alternative Conceptions movement and the Cognitive-Developmentalist position should be encouraged to consider the commonalities of their theoretical positions (constructivism) and practice (cognitive conflict and metacognition) and be prepared to enter into an open-minded debate to explore differences such as their emphases on stages or on preconceptions. Even if these differences were swept under the carpet there would remain a significant difference in aims: interventionists using a cognitive developmentalist model are aiming for general intellectual development regardless of content, whilst teaching programmes based on Alternative Conceptions work aims at pupils constructing concepts more in line with those accepted by the scientific community. This difference can be seen in a positive light. Both are equally necessary; neither can succeed without the other. Together we could show politicians really how to raise standards.

REFERENCES

Adey P.S., Shayer M. & Yates C. (1989) Thinking science: the curriculum materials of the CASE project. London: Thomas Nelson

Adey, P.S. & Shayer M. (1992). An exploration of long-term far-transfer effects following an extended intervention programme in the high school science curriculum, Cognition and Instruction, in press

Ausubel D. (1968). Educational psychology: a cognitive view. New York: Holt Rinehart & Winston

Champagne A. B., Gunstone R.F., & Klopfer L. (1985). Effecting changes in cognitive structures amongst physics students. in L.H.T West & A.L. Pines (eds) Cognitive structure and conceptual change. Orlando: Academic Press

CLISP [Children's Learning in Science Project] (1987). Approaches to teaching. Leeds: Centre for Studies in Science and Mathematics Education.

Driver, R. (1983). The pupil as scientist? Milton Keynes: Open University Press.

Driver R., Guesne, E. & Tiberghien, A. (eds) (1985) Children's ideas in science. Milton Keynes: Open University Press.

Gauld, C. F. (1986). Models, meters and memory. Research in Science Education, 16, 49-54

Glaserfeld, E. von (1987). The construction of knowledge. Seaside CA: Intersystems Publications.

Guesne, E. (1985). Light. In R. Driver, E. Guesne & A. Tiberghien (eds) (1985) Children's ideas in science. Milton Keynes: Open University Press

Inhelder, B. & Piaget, J. (1958) The growth of logical thinking. London: Routledge Kegan Paul.

Karplus, R. 1979. Teaching for the development of reasoning. In A.E. Lawson (ed) The psychology of teaching for thinking and creativity. Columbus OH: ERIC-SMEAC.

Kuhn, D., Amsel, E., & O'Loughlin, M. (1988). The development of scientific thinking skills. San Diego: Academic Press.

Latour, B. & Woolgar S. (1973). Laboratory life: The social construction of scientific facts. Beverley Hills CA: Sage Publications.

Lawson, A.E. (1989). Research on advanced reasoning, concept acquisition, and a theory of instruction. In P.S. Adey, J. Bliss, J. Head , & M. Shayer, (eds) Adolescent development and school science. London: Falmer Press

Monk, M. (1990). A genetic epistemological analysis of data on children's ideas about DC electrical circuits. Research in Science and Technological Education, 8 (2), 133-143.

Monk, M. (1991). Genetic epistemological notes on recent research into children's understanding of light. International Journal of Science Education 13 (3), 255-266.

Novak J. D. (1987). Human constructivism: towards a unity of psychological and epistemological meaning making. In Proceedings of second international seminar on misconceptions and educational strategies in science and mathematics education. Ithaca NY: Department of Education, Cornell University

Osborne R.J. (1981). Children's ideas about electric current. New Zealand Science Teacher. 29, 12-19.

Osborne R.J. (1983). Towards modifying children's ideas about electric current. Research in Science and Technological Education, 1, 73-82

Osborne R.J. & Freyberg, P. (1985). Learning in science: The implications of children's science. Auckland: Heinemann.

Ramadas, J. & Driver, R. (1989). Aspects of secondary students' ideas about light. Leeds: Children's Learning in Science Project.

Ramadas, J. & Driver, R. (1991). Response to Martin Monk's paper, 'Genetic epistemological notes on recent research into children's understanding of light.' International Journal of Science Education 13 (3), 266-268.

Shayer, M., Küchemann, D.E., & Wylam, H. (1976). The distribution of Piagetian stages of thinking in British middle and secondary school children. British Journal of Educational Psychology, 46, 164-173

Shayer, M., & Wylam, H. (1978). The distribution of Piagetian stages of thinking in British middle and secondary school children. II 14- to 16- year olds and sex differentials. British Journal of Educational Psychology, 48, 62-70

Shayer M. & Adey P.S. (1981). Towards a science of science teaching. London: Heinemann Educational.

Shipstone, D.. M. (1984). A study of children's understanding of electricity in simple d.c. circuits. European Journal of Science Education, 6 (2), 185-198.

Vygotsky L.S. (1978). Mind in society. Cambridge MA: Harvard University Press.

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DISCIPLINE KNOWLEDGE AND CONFIDENCE TO TEACH SCIENCE: SELF-PERCEPTIONS OF PRIMARY TEACHER EDUCATION STUDENTS

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ABSTRACT

There has been renewed debate in recent years about the relatively poor science discipline background knowledge of primary and pre-school teachers, and their lack of confidence to teach science stemming from this. A reaction from teacher educators, such as recommended by the *Discipline Review of Teacher Education in Mathematics and Science* Report, has been to provide more explicit science discipline units in pre-service teacher education courses. However, a few studies have cast some doubt on the notion that more science discipline studies help preservice teachers become more positive about teaching science (Skamp, 1989; Stepans & McCormack, 1985). This paper reports on pre-service students' perceptions of their confidence to teach science before and after a science education unit adapted from the PECSTEP work (Kirkwood, Bearlin & Hardy, 1989), which included only a small amount of physical science, and took an explicit gender approach emphasising the students as learners.

INTRODUCTION

The reluctance of many Australian primary teachers to teach science has been well documented (Australian Foundation for Science, 1991; Henry, 1977; Owen, Johnson & Welsh, 1985; Symington, 1974; Varley, 1975; Yates & Goodrum, 1990); a phenomenon also common to other countries (for example, New Zealand: Biddulph, 1982; Britain: HMI, 1978; North America: Manning, Esler & Baird, 1982; Schoeneberger & Russell, 1983). Reasons for this reluctance have often been expressed in terms of primary teachers' lack of confidence to teach science, stemming from a generally low level of science discipline knowledge (Appleton, 1977; Biddulph, 1982; DEET, 1989; Perkes, 1975; Schoeneberger & Russell, 1983). Teacher education students with little science discipline knowledge also express lower confidence in teaching science, particularly the areas of science which they know least about (Appleton, 1991; Dooley & Lucas, 1981; Skamp, 1989).

While the need for teachers to have greater confidence in their ability to teach primary science has been recognised for decades, it has been under a sharper focus in Australia since a government review of science teacher education programs was conducted (DEET, 1989). The committee conducting the review felt that teachers' confidence would be improved if they had a stronger science discipline knowledge base, and recommended that minimum periods of science discipline units be included in preservice programs (DEET, 1989). Although many Victorian teacher educators agreed with the view that a stronger science discipline base was necessary for teacher education students, they tended to disagree with other recommendations which suggested explicit assessment of science knowledge, use of diagnostic tests for remediation, and the time to be spent on discipline studies (Symington & Mackay, 1991). Such dissension highlights the lack of knowledge about how much discipline knowledge is necessary to improve teachers' and student teachers' confidence to teach science, and what specific effects improved knowledge may have on teaching practices.

Some aspects of the latter have been explored (for example, Symington, 1980, 1982; Symington & Hayes, 1989), but little is known of the former. Skamp (1989) found that more science discipline knowledge did not improve science students' attitudes to science, but that teacher education students showed a positive attitude change to teaching primary science after a science education unit. This finding suggests a tenuous link between discipline knowledge and confidence to teach science. Similarly, Stepans and McCormack (1985) found that students who took more traditional science courses at college did not necessarily have greater understanding of science concepts, improved attitudes to teaching science, or self-confidence in teaching it. This paper addresses the question of whether discipline knowledge is necessary for teacher education students to feel more confident about teaching science, and provides some insights into other factors which may influence their confidence to teach science.

THE STUDY

The 139 students in their first year of a three-year preservice primary and preschool teacher education course at the then University College of Central Queensland studied a compulsory science education unit adapted from the Primary and Early Childhood Science Teacher Education Project (PECSTEP) at Canberra University (Kirkwood, Bearlin & Hardy, 1989). The unit took an explicit gender focus, and emphasised the students as learners in a constructivist context, along the lines suggested by Hardy and Kirkwood (1991). A small amount of science discipline knowledge was included in the unit, mainly drawn from the physical sciences arising from an investigation of a toaster using the *Interactive Approach* (Biddulph & Osborne, 1984). The students completed identical surveys at the beginning and end of the unit. Part of the surveys explored the students' self-perceptions of their teaching of science and technology (see Table 1). Each survey item consisted of a five-point Likert scale, coded one (high) to five (low). A few months after the completion of the semester, nine students were interviewed to ascertain aspects of the science education unit which had been influential in helping them change their self-perceptions. Three students from each of five class groups were randomly selected, but six declined the invitation to participate.

The interview questions probed the students' remembered feelings about teaching science before and after the science curriculum unit, whether their ideas had changed as a result of the unit, and what aspects of the unit had contributed to the changes they had commented on.

The structured interviews, conducted by a person other than the lecturer who taught the science education unit, were audio taped for later analysis. Further data were obtained from anonymous student evaluations of the unit.

Analyses

Although the survey data were ordinal in nature, analysis of variance and t-tests were considered sufficiently robust to be used. Analysis of variance was used to ascertain whether the posttest scores were statistically different from the pretest scores, and paired t-tests were used to identify particular items where significant differences equal to or less than the 0.05 level existed. The survey analysis was used to identify any differences in students' perceptions across the semester.

TABLE 1
PRETEST AND POSTTEST SCORES FOR SURVEY ITEMS (N = 139)

Item **Student perceptions of their:**	**Pretest Mean**	**Standard Deviation**	**Posttest Mean**	**Standard Deviation**
Level of interest in teaching science (high/low)	2.4	0.9	2.1	0.7^1
Level of interest in teaching technology	2.7	0.8	2.4	0.7^2
Level of interest in teaching life	1.8	0.8	1.8	0.7
Level of interest in teaching energy	2.5	0.8	2.3	0.8^2
Level of interest in teaching matter	2.7	0.8	2.5	0.8^1
Level of interest in teaching earth	1.9	0.8	1.9	0.8
Level of interest in teaching space	2.2	1.0	2.0	0.8^3
Background knowledge for teaching science (extensive/less than adequate)	3.6	0.9	2.8	0.9^1
Background knowledge for teaching technology	3.9	0.9	3.2	0.8^1
Background knowledge for teaching life	3.0	0.9	2.6	0.9^1
Background knowledge for teaching energy	3.5	0.9	2.9	0.8^1
Background knowledge for teaching matter	3.7	0.9	3.0	0.8^1
Background knowledge for teaching earth	3.2	0.9	2.7	0.8^1
Background knowledge for teaching space	3.4	1.0	2.8	0.9^1
As a future teacher I think my teaching of science would be (competent/not so great)	2.5	0.9	2.2	0.8^1
As a future teacher I think my teaching in technology would be ...	2.9	1.0	2.6	0.8^2
Attitude to teaching science scale (8 - most positive; 56 - most negative)	23.3	7.2	21.7	7.3^3

[1] Probability less than or equal to 0.001
[2] Probability less than or equal to 0.01
[3] Probability less than or equal to 0.05
Ratings were on a five point scale, with one the highest rating

The interview and evaluation data were used to provide insights about trends identified in the surveys. The interview data were transcribed and searched for statements which were relevant to the students' perceptions of the success or otherwise of aspects of the science education unit. Comments made by students anonymously in unit evaluations were collated and categorised using exemplars. Statements made by students in assessed assignments which also shed light on the trends identified in the survey data were extracted and collated.

SURVEY RESULTS

The means and standard deviations for each relevant survey item in both the pretest and posttest are presented in Table 1. Significance levels for each item, as revealed by the paired t-tests, are indicated. It can be seen that most posttest means are significantly less than the pretest means, which indicates a positive change in students' rating for those items. The two items for which there was no significant change were the students' expressed level of interest in teaching life and earth topics. The pretest means for these items were quite low compared to other items, so no significant change occurring in them is not surprising.

Items in the pretest which have the highest mean are the students' perceptions of their background knowledge to teach science, particularly matter, space and energy, and to teach technology. It was these areas which the students were therefore least confident about, and which also showed the greatest changes in the pretest-posttest comparisons.

DISCUSSION OF SURVEY DATA

The pretest data in Table 1 show a typical pattern for primary and early childhood teachers revealed in other studies (for example, Australian Foundation for Science, 1991; Varley, 1975). While the students in this study tend to have a moderate interest in teaching science and technology, many also feel their background knowledge barely adequate to teach them. This is particularly so for the conceptual areas of energy, matter and space. Relatively few feel that, as future teachers, their teaching of science or technology would be competent, though a fair number think it would be reasonable. It is the low perceptions of adequacy of background knowledge which prompted calls for discipline knowledge to be included in preservice courses (DEET, 1989).

Since the pretest-posttest data reveal statistically significant changes for most items in the positive direction, it can reasonably be assumed that the unit on science education was largely successful in effecting change in the students' perceptions of themselves as teachers of science and technology. The items of greatest interest are those dealing with the students' perceptions of the adequacy of their background knowledge. Not only were there significant positive changes in the students' perceptions of their adequacy to teach science and technology overall, all five content areas in science showed similar positive changes. These changes cannot be due to the students' study of science knowledge itself, as only the area of energy was included in the science education unit. These findings reflect those of Skamp (1989), who found a science pedagogy unit had positive effects on students' confidence to teach science. Clearly then, something happened in the science education unit which changed many students' perceptions of themselves and their existing knowledge. It may be that the mere fact that a science and technology education unit is studied by the students is sufficient to enhance their self-confidence about teaching science and technology, but the survey data do not reveal details of what in the unit contributed to the students' changed self-perceptions. However, the interviews provided some insights into this.

THE INTERVIEW DATA

Of the nine students interviewed, eight reported that the science curriculum unit had resulted in positive changes in their views about teaching science. One student felt that the unit had not generated any changes in perceptions about teaching science. There were two key areas of change on which the majority of interviewees commented. They reported a change in their perception of the nature of science teaching, and a change in their own self-perceptions as teachers of science.

Their perception of the nature of science teaching

Prior to the course, many students saw teaching science as a highly structured and didactic process whereby the teacher told the children a lot of content, which was perhaps reinforced by laboratory work:

> *Before the course, I imagined teaching science as standing up in front of the classroom and telling them all the scientific laws and here is an experiment and we will do this and then write what happens on the board, what the Law said.*
>
> *I thought (teaching science) was mainly standing out in front teaching kids out of a text book more or less.*

As a result of the science curriculum unit, eight of the students interviewed reported changed perceptions of the nature of science teaching. Six commented on a realisation that the teacher did not have to know everything about a topic in order to teach it - some knowledge was necessary, but the teacher could also learn with the children.

> *It (the science curriculum unit) made me realise it is not necessary - it is necessary to have content, but you can actually learn it as you are going through with the kids and you should have a good understanding of it before you actually teach something. But you can also catch onto a lot of things as you are doing it with the kids.*
>
> *I think one of the main things the course taught me was "you can learn with the children". The teacher does not have to have all the knowledge - you can discover things together in science...you need to have a certain knowledge on the subject first, but you do not have to know everything.*

Their own self-perceptions of themselves as teachers of science

The students also commented in various ways on how they now felt more confident to teach science.

> *Through doing the course, though, I do feel a lot more confident.*
>
> *I think the main thing (from the unit) would be that I feel more confident now about going and teaching science, even though...my knowledge of science is very limited...It just made me feel more comfortable about going out and teaching science in schools, when I go.*

Aspects of the course which caused these changes

The main aspect of the course mentioned by all students who reported changes in perceptions was the way the subject was taught. All key components were mentioned positively, but the most frequently mentioned was the way the science content was taught. The students not only were successful in learning science content, but also learnt an effective way to teach science.

> *Just the experience, the actual experience in the science tutorials and then out in the schools. This gave me reinforcement, and I discovered I could teach science.*
>
> *(The lecturer) has shown us how you do not have to particularly direct and be authoritarian in your approach to teaching (science), and you can actually provide the support and facilitate the kids (learning). That is what he did with us - to be encouraged to come and take risks a little bit further than what I would probably have done beforehand.*

From the interview data, it would appear that the students interviewed had gained more positive perceptions about teaching science from the pedagogy employed. This pedagogy enabled them to achieve success in learning science, but also enabled them to see that science teaching was within their grasp, rather than being the preserve of the very talented scientifically. Further, they were able to experience success in teaching science to children using the pedagogy they had seen modelled. These findings reflect those from others who have employed a similar pedagogy in preservice and inservice settings (Hardy & Kirkwood, 1991).

THE EVALUATION DATA

Data from student evaluations of the unit and comments made in assessed assignments were used to gain further understandings about the effects of the unit on students' perceptions. Submission of anonymous, open-ended evaluation comments was voluntary. Of the 55% of students who made comments, 71% made positive statements about the unit, 17% made neutral comments, and 12% made negative comments. Comments offered by some students paralleled those made in the interviews.

> *I thoroughly enjoyed science, which came as a surprise to me. I have always felt intimidated by the content and knowledge. (The lecturer) made me and the rest of the group (of students) feel comfortable with it.*

The evaluation data support the trends identified in the surveys, and give clear indications that the positive changes in students' perceptions were due to the pedagogy employed in the subject. Key aspects of the pedagogy seem to have been related to the foci of the unit (gender equity, constructivism, and science as a dynamic, people-oriented subject) and the role played by the lecturer (Hardy & Kirkwood, 1991). Each of these was explored through the literature, discussed by the students, and modelled in class. As well as the students coming to see science and science teaching in a different way, they also experienced success in accessing science knowledge for themselves, albeit in a very restricted field of science. The following statement made by a student on the sixth week of the unit summarises the nature of the changes experienced by the majority of students, and suggests a basic source of the problems with science that many students encounter:

> *During school, science was all information and writing. Science was laborious and boring. That one afternoon (each week) called "science" imprinted bad attitudes not only on me but also on my fellow classmates, towards science. What a relief it was to find that this subject was not all facts and figures but actually fun, not to mention interesting.*

CONCLUSION

While these data reveal that a science education unit with particular characteristics can have dramatic effects on students' self-confidence to teach science and technology, self-confidence should not be confused with competence. Unless the students also increase their grasp of science/technology content, it could be argued that many will remain incompetent to teach the subject, though this has not been clearly demonstrated. Several students, on the other hand, felt that a small amount of knowledge was sufficient for the teacher, provided they approached the teaching of it as co-learners with the children.

There are general points about teaching science discipline knowledge in preservice and, by extrapolation, inservice courses which can be learned from this study. Firstly, science discipline knowledge needs to be taught in a way which will give students a more positive self-image of themselves as teachers of science and technology. Teaching discipline knowledge without taking this goal into consideration may do more harm than good: students' self-perceptions may well remain largely negative, and may even become more negative. Secondly, the teaching strategies which have proved effective in generating positive changes in self-perception tend to be time consuming, and need to be conducted in small group settings rather than large lectures. This means that the amount of content "covered" would usually be less than that delivered in large group lectures. That is, what is gained in students' self-confidence, is paid for by covering less content. The small group teaching also means more expensive teaching compared to traditional lecture and laboratory methods. Thirdly, once students' self-confidence is improved, many could be expected to access science and technology content for themselves through individual research and/or normal science courses. While not proven, this is a reasonable hypothesis given the changes documented in this study and others (Kirkwood, Bearlin & Hardy, 1989). Ideally, a preservice course should therefore contain at least two compulsory science and technology education units: the first based on strategies such as those outlined here, and the second a more specific focus on discipline knowledge. However, restrictions on the number of compulsory science education units able to be included in a preservice course may make independent study the only viable means for many students to gain further science and technology discipline knowledge.

As documented at the beginning of this report, many primary and early childhood teachers need to improve their confidence to teach science, and their science discipline knowledge. The findings of this study suggest that the pedagogy employed in at least the first units studied by such teachers is crucial to their being able to access science knowledge and teach science confidently in their classrooms. Nor should the content of the first units studied be solely science discipline knowledge - gender equity, constructivism and the nature of science also need to be included.

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REFERENCES

Appleton, K. (1977). Is there a fairy godmother in the house? Australian Science Teachers Journal, 23 (3), 37-42.

Appleton, K. (1991). Mature-age students: How are they different? A paper presented at the annual conference of the Australasian Science Education Research Association, Gold Coast, July.

Australian Foundation for Science. (1991). First steps in science and technology. Focus on Science and Technology Education No. 1. Canberra: Australian Academy of Science.

Biddulph, F. (1982), Primary science: The views of teachers and pupils. Working Paper No. 102, Learning in Science Project (Primary). Hamilton, N.Z.: Science Education Research Unit, University of Waikato.

Biddulph, F. & Osborne, R. (1984). Making sense of our world: An interactive teaching approach. Hamilton, N.Z.: SERU, University of Waikato.

DEET (Department of Employment, Education and Training). (1989). Discipline review of teacher education in mathematics and science. Canberra: Australian Government Publishing Service.

Dooley, J. & Lucas, K. (1981). Attitudes of student primary teachers towards science and science teaching. Australian Science Teachers Journal, 27 (1), 77-80.

Hardy, T. & Kirkwood, V. (1991). Toward creating effective learning environments for science teachers: The role of the science educator in the tertiary setting. A paper presented at the annual conference of the Australasian Science Education Research Association, Gold Coast, July.

Henry, J.A. (1977). Victorian primary science: Five years on. Australian Science Teachers Journal, 23 (1), 49-55.

HMI (Her Majesty's Inspectorate). (1978). Primary science in England: A survey by H.M.Inspectors of Schools. London: Department of Education and Science, HMSO.

Kirkwood, V., Bearlin, M. & Hardy, T. (1989). New approaches to the inservice education in science and technology of primary and early childhood teachers (Or Mum is not dumb after all). Research in Science Education, 19, 174-186.

Manning, P.C., Esler, W.K. & Baird, J.R. (1982). How much elementary science is really being taught? Science and Children, 19 (8), 40-41.

Owen, J.M., Johnson, N.J. & Welsh, R.J. (1985). Primary concerns: A project on mathematics and science in primary teacher education. Canberra: Commonwealth Tertiary Education Commission.

Perkes, V.A. (1975). Relationship between a teacher's background and sensed adequacy to teach elementary science. Journal of Research in Science Teaching, 12, 85-88.

Schoeneberger, M.M. & Russell, T.L. (1983). Add a little frill: Science in the elementary school. A paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada, April.

Skamp, K. (1989). General science knowledge and attitudes towards science and science teaching of pre-service primary teachers: Implications for pre-service units. Research in Science Education, 19, 257-267.

Stepans, J. & McCormack, A. (1985). A study of scientific conceptions and attitudes toward science of prospective elementary teachers: A research report. A paper presented at the meeting of the Northern Rocky Mountain Educational Research Association, Jackson Hole, WY, October.

Symington, D. (1974). Why so little primary science? Australian Science Teachers Journal, 20 (1), 57-62.

Symington, D. (1980). Primary school teachers' knowledge of science and its effect on choice between alternative verbal behaviours. Research in Science Education, 10, 69-76.

Symington, D. (1982). Lack of background in science: Is it likely to always adversely affect the classroom performance of primary teachers in science lessons? Research in Science Education, 12, 64-70.

Symington, D. & Hayes, D. (1989). What do you need to know to teach science in the primary school? Research in Science Education, 19, 278-285.

Symington, D. & Mackay, L. (1991). Science discipline knowledge in primary teacher education: Responses to the Discipline Review of Teacher Education in Mathematics and Science. Research in Science Education, 21, 306-312.

Varley, P.J. (1975). Science in the primary school. Brisbane: Research Branch, Department of Education, Queensland.

Yates, S. & Goodrum, D. (1990). How confident are primary school teachers in teaching science? Research in Science Education, 20, 300-305.

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TEACHER BELIEFS ABOUT LEARNING AND TEACHING IN PRIMARY SCIENCE AND TECHNOLOGY

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ABSTRACT

It is argued that the introduction of many new curricula with their associated teaching practices have failed because the beliefs, views and attitudes of teachers have been ignored. This paper reports the implications of the initial beliefs of primary school teachers involved in a professional development program about science and technology education. In particular, a mismatch between teachers views of learning and teaching is identified and analysed.

INTRODUCTION

The introduction of new curricula with their associated teaching practices, although well founded on learning theory, pedagogy and empirical research, has failed because the conceptions, beliefs, views and attitudes of teachers were often ignored (see Mitchener & Anderson, 1989; Richardson, 1989). Teachers have been at best regarded as a conduit for change; at worst as "a bothersome intervening variable" or "stone-age obstructionists" (Richardson, 1989, p. 379). Furthermore, changes in teaching practice have not been widely implemented because the way in which teachers teach matches their image of science teaching and their knowledge of and about science (Tobin, 1990; Gallagher, 1991).

Many have argued for the need to study such teacher conceptions. Briscoe (1991), for example, claims that an individual commitment to change is not enough. If changes are to occur in teaching practice, teachers must examine their beliefs, judgements, and thoughts regarding what they do and why they do it. Hewson and Hewson (1989, p. 191) state that if we wish to improve science teaching, a key question which needs to be answered is, "What thoughts most influence a teacher's teaching?" Richardson (1989, p. 389) argues that, "Coming to understand the 'meanings and concepts' of experienced teachers about their practice is...the responsibility of those who would enable teachers to change the way they teach..."

The challenge for science and technology education research in the 1990's, is to bring about a change in teaching so that theory and classroom practices are more closely aligned. To meet this challenge there is a need "to identify how teachers can construct knowledge about content and teaching so that their teaching performance improves" (Tobin & Fraser, 1987, p. 213).

The need for teachers to investigate, develop, internalise and consistently apply science and technology understandings, curriculum innovations and developments in pedagogy in a way that is satisfactory to them is not dissimilar to the need for children to investigate, develop, internalise and apply understandings of science in a way which is satisfactory to them. Interactive models of learning based on constructivist principles may provide a means by which these goals can be achieved (Osborne & Freyberg, 1985). Therefore, teachers should be encouraged to explore their conceptions, those of others and test them against experience and in trials.

The present study

The aims of this research were to investigate

- teacher perceptions of their confidence to teach science and technology and their perceptions of what is important in science and technology education,
- teacher conceptions of learning and teaching in science and technology education.

The participants were 40 teachers in the Primary Science Teacher Education Program (PRIMESTEP). The program was presented in two residential blocks, the first over five days and the second over three days with a 10 week break between blocks. Each of 10 school regions in NSW was asked to select participants for PRIMESTEP on the basis of their expertise, enthusiasm or interest in science and technology education. Therefore, they were a targeted group and are not a representative sample of NSW primary school teachers.

Three different methods of data collection were used: before and after surveys; participant/participant interviews; and records of teacher generated metaphors.

SURVEY

Participants were surveyed at the start of the first and at the end of the second PRIMESTEP residential blocks. A questionnaire was designed to obtain participants' personal and demographic details, their perceptions of science and technology and the new science and technology syllabus, their confidence in science and technology education and their conceptions of how children learn in science and technology. The second questionnaire was a subset of the first.

The quantitative data related to the participants' ratings of items according to their importance in science and technology education and their confidence in teaching science and technology were compared using ANOVA with repeated measures and Scheffé test. The changes in these items between the first and second surveys were compared using two tailed correlated t-tests.

The qualitative data obtained in response to the open ended question in the surveys, 'how do children learn in science and technology?', were analysed and categorised in order to identify general trends. Categories were grounded in the data and in some cases clarification of responses was sought from participants.

Results and Discussion

Confidence Participants were asked to rate their confidence to teach science and technology on a four point scale from 1 = not to 4 = extremely confident. Before PRIMESTEP the participants were fairly confident about teaching science and technology (mean = 2.5). After PRIMESTEP, the participants were significantly more confident (mean = 3.1, $t = 4.49$; $p < .0001$). The high rating of their confidence to teach primary science and technology may be atypical of other teachers given the select nature of this group but does attest to the effectiveness of PRIMESTEP in increasing teacher confidence.

What's Important in Science and Technology Education? Participants were asked to rate the importance of 12 items in primary science and technology education on a five point scale from 1 = low to 5 = high importance (see Rennie, Parker & Hutchinson, 1985). The 12 items consisted of two sets of items, those specifically related to science and technology (Set 1; see Table 1) and those related to all subjects (Set 2; see Table 2). The importance ratings of the 12 items in the first and second surveys were compared using a two tailed t-test and no significant differences in the ratings of any items was obtained. This suggests that the participants have constructed beliefs about what is important in science and technology education and these are resistant to change.

ANOVA with repeated measures was used to compare the ratings of the items within each set. Significant differences were found between the ratings of the science and technology items in set 1 (F between items = 16.15; df = 6, 234; $p < .0001$). The lowest mean ratings were obtained for Development of Knowledge and Manipulative Skills, followed by Preparation for Careers in Science and Technology. Follow-up tests revealed significant pair-wise differences as shown in Table 1 where any two means not joined by asterisks are significantly different ($p < .05$).

TABLE 1.
PAIRWISE COMPARISON OF IMPORTANCE RATINGS OF SCIENCE AND TECHNOLOGY RELATED ITEMS USING SCHEFFÉ TEST

	Prob. Solving	Interest in S&T	Relevance	Creativity	Career Prep.	Manip. Skills	Knowledge
Mean	4.8	4.7	4.6	4.5	4.0	3.8	3.6

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Significant differences were also found between the ratings of the items related to all key learning areas, set 2 (F between items = 7.723; df = 4, 152; $p < .0001$). Follow-up tests revealed significant pair-wise differences as shown in Table 2 where the rating of Written Skills was significantly different from other interactive skills i.e. Social and Verbal Skills ($p < .05$).

TABLE 2.
PAIRWISE COMPARISON OF IMPORTANCE RATINGS OF ITEMS RELATED TO ALL LEARNING AREAS USING SCHEFFÉ TEST

	Social Skills	Verbal Skills	Self Discipline	Integrating Subjects	Written Skills
Mean	4.5	4.2	4.1	4.1	3.7

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Of the 12 items, the development of scientific and technological knowledge was rated lowest in importance. This was surprising since, in the PRIMESTEP course evaluation when participants were asked to respond to the open ended question, 'What was the most important thing that you got out of the course?', the most common response was knowledge and understanding. After the 10 week break the participants were asked to explain why knowledge and understandings were important for them but relatively unimportant for their pupils. This question was followed by a long pause (a very unusual occurrence on this course). When they responded they said that they did not believe they had rated it lowest in importance, that the teacher needed to know to be confident about what was being taught, that the teacher needed to apply the knowledge and anticipate the pupils learning outcomes. Further research is needed to determine how much primary school teachers think they need to know and whether their perception of the need to know inhibits their teaching of certain content in primary science and technology. Evidence is provided later that one of the reasons teachers fail to teach science and technology is because they perceive they lack the necessary scientific and technological knowledge. It is tempting to suggest that by rating the development of science and technology knowledge by pupils as relatively unimportant their own lack of knowledge becomes unimportant and their self esteem as teachers is thereby protected.

INTERVIEWS

During PRIMESTEP the participants were asked to maintain a journal in which they recorded their responses to a variety of reflection tasks. In one task, each participant was asked to interview another to determine views of how teachers should teach science and technology and then of how children learn in science and technology. The interviewer then summarised the views of the interviewee in the journal. When the summaries were finished the participants commented on whether the views on learning and teaching described were consistent and whether teachers taught in the way that it was said they should. This task was completed at the start of the course but after the survey.

In order to identify and justify the existence of the general trends and key ideas two researchers independently analysed the data. The results were compared. Evidence was sought to verify these interpretations.

Results and Discussion

Views of Learning The participants seemed to experience little difficulty in clearly explaining how they believed children learn. Children were said to learn in a variety of ways. The following summary of views of how children learn is ranked approximately in order from most to least commonly expressed in interviews.

- By Interacting with Materials and Environment, by 'Doing', 'Hands on', by the Scientific/Technological Processes eg, 'by designing and making', 'by Investigating', 'by trying, testing ideas', 'by applying ideas'.#
- By Interacting with Others, Cooperating/Sharing/ Discussing e.g. 'by working with others', 'by sharing', 'by working in groups'.
- When Motivated/Interested, Enjoyment e.g., 'fun', 'arousing Interest', 'by being motivated', 'by being stimulated'. (Motivation was usually viewed as extrinsically generated, coming from the teacher or science and technology activities.)

- By Thinking/Reflecting, Changing/Constructing their Own Ideas # e.g. by 'forming new ideas when they have seen what they have done', 'modifying ideas', 'creating a view of their world'.
- From Experiences # e.g. 'from their life experiences', 'from everyday experiences'.
- From Teaching, Guided Discovery eg, 'by being guided by the teacher' or By Being Directed eg, 'by being informed', by 'valuing the children's ideas'.

  (# These views were very rare in the survey but more common in the interviews.)

The views of learning espoused in both surveys and interviews were consistent. In the interviews these were typically complex in that each participant identified a greater range of components of learning than in the survey but all of these were invariably identified by some of the participants in the survey. Their ability to express these ideas clearly suggests that they have meaningfully constructed beliefs about learning. However, it may simply represent an ability to repeat and link clichés together to form sensible statements rather than an articulation of their own beliefs. The consistency of the data on learning obtained from a range of sources, reported later, implies the latter.

Views of Teaching Those who were able to clearly define the teacher's role tended to describe it in a mechanistic way. The descriptions outlined what the teacher does before and after learning but very rarely explained what the teacher does when children are actually learning. That is, before learning begins, the teacher plans, motivates, sets up the activity, organises groups. After learning the teacher assesses and evaluates. During learning few clear indications are given; some vague references to 'questioning' and acting as a 'guide'. Many defined their role in the negative by stating what they do not do. The following summary of views of how teachers should teach is ranked approximately in order from most to least commonly expressed in interviews.

- By Organising of the Tasks, Environment and Resources eg, 'structuring stimulating situations', 'sequencing activities', 'planning', 'adequate prior preparation',
- By Assessing/Evaluating eg, 'diagnose the pupils knowledge and skills', ' the teacher would engage in purposeful evaluation'
- By Motivating eg, 'provide an enthusiastic and comfortable atmosphere', 'interest and excite the student's natural enthusiasm', 'provide exciting, interesting activities for students... match them with the interests of the students.'
- By Setting up and Managing Groups eg, 'teachers should involve students in group work', 'students placed in groups to cater for diversity of student knowledge and skills'.
- By Interrogating eg, 'by asking questions', 'keep children on task: prompt and probe.'
- By Not Doing Things eg, 'no chalk and talk', 'not too much demonstration', 'not waste kid's time by drawing pretty pictures of experiments', 'not... demonstration style'.
- By Modelling Learning eg, 'by modelling learning', by 'learning with them (the pupils)'

The summaries of the participants' views of teaching often outlined these teaching and learning processes but rarely made connections between them. Very few teachers stated what their role was in the learning process. When asked about teaching, many teachers stated how they thought children learn. For example, 'Children learn by investigating their own ideas and experimenting', 'They learn by solving problems'. In this way, when they attempted to outline the teachers role while children were actually learning, they tended to refer to what the children were doing or how they would be organised. There were some notable exceptions to this pattern when teachers did attempt to describe a role for the teacher during learning. For example,

> ...the teacher providing ideas and materials, they(sic) present a problem and discuss possibilities. ... Teacher's role is to assist and guide, to help children to think through own solutions. Teacher should observe, question, discuss and guide and provide the opportunities for learning.

It seems that the participants have a clear view of how children learn and their role as an organiser of the learning environment but rarely did they explain how they would promote thinking, reflection and the modification of ideas, cooperative learning, investigating and designing and making. Yet, these were all identified as being ways in which children learn. It is as if the teacher had no role at all when the children are learning.

The participants did not see any inconsistency between their views of learning and teaching. This is not surprising since when many described teaching they did so by describing learning. For example, they often referred to 'child centred learning' and 'cooperative learning' when discussing teaching. They defined their role by defining the children's role.

METAPHORS OF TEACHING AND LEARNING

After the participant/participant interviews, a short lecture was given in which a variety of teacher metaphors were considered. Participants were then asked to construct their own personal teacher metaphor of how they thought they should teach. When this was done they derived a metaphor for their pupils. They were then asked whether they were satisfied with their metaphor? Finally they were asked whether the metaphors described were consistent with the views of teaching and learning summarised in the interviews.

The procedures used to analyse the interviews were also used in the analysis of metaphors. The views about learning and teaching expressed in the surveys, interviews and metaphors were compared. Similarities and differences among these were identified.

Results and Discussion

Although the teachers typically described teaching and learning as 'child centred', the vast majority of personal teacher metaphors were teacher centred eg. 'captain of a ship', 'architect', 'pianist', 'musician', 'entertainer', 'conductor', 'torch'. The teacher metaphors portrayed the teacher as an 'organiser' and 'controller' who brought together individuals for a purpose organised by the teacher. The children were characterised as 'members of a team', 'keys on a piano', 'members of the crew', 'builders following a plan' and 'sponges absorbing the light'! For example,

> I (the architect) provide the plans (basis) from which the children build their "buildings": some branching out from the basic design...They are building on what I have planned for them.

Such metaphors indicate, at a personal level, that many teachers still see themselves teaching in a teacher centred environment in contrast to their articulated views about 'child-centred' learning.

A minority of participants recognised the inconsistency between the metaphors of teaching they described and their summaries of how to teach and how children learn in science and technology. In one instance the teacher saw herself as the 'conductor' and the children as 'members of an orchestra'. When she realised the inconsistency she changed the metaphor to that of a 'musician'. The children thus became the musical 'instruments' upon which she played and she, like others who reflected on this inconsistency, experienced cognitive dissonance.

> After reflecting, I think my role/metaphor, to be more of the musician - because its the musician who plays the instruments. This would then mean the children become the instruments. ... If I'm the musician, the students are the instruments. Who then is the conductor?

The inconsistency of the teacher metaphors and the fluidity of the thinking expressed in some of the metaphors contrasts with the consistent pattern of views expressed about learning across two surveys, an interview and a metaphor. Even where teacher centred metaphors were described the metaphor given for the learner still managed to imply that the learner had some control and operated with considerable independence. The builders did their own building of understandings, the crew on the ship had to take 'responsibility for their own actions', the musicians and instruments were 'creative', members of the football or basketball team 'cooperated' while on the field/court 'away from the coach' and the audience 'interacted'. This implies that teachers have constructed a fixed and definite view about learning.

In contrast, the conceptions of teaching appear to be undergoing change, or perhaps the participants have two distinct views of teaching. One says what they should do, as expressed in the interview, and this involves 'child centred' approaches but appears to be inadequate because it does not describe what they are doing when the children are learning. The other view which arises in the metaphors, also clearly states what they feel they should do but this is teacher centred. These metaphors place the teacher firmly in control and at the centre of attention. There appears to be a clear perception of how they want children to learn but these child centred approaches demand a change in teaching practice. It is the nature of these teaching practices that they are not sure about and therefore they retreat or 'revert' to practices about which they feel more confident but which are more didactic and hence in conflict with their perceptions of learning.

In child centred learning, the participants clearly state that the teacher's role is to keep out, and not to intervene. This conflicts with their personal view of the role of the teacher described in the metaphors. This conflict was at times identified by the participants. For example,

> I need to become a coach who can leave the game to the players once it is in progress and wait till half time to be able to have more input. I must admit, at this stage, I would probably be a coach who runs on to the court during the game when you see a problem arising.

Why don't teachers teach in the way they say they should? When asked whether they teach the way they said they should, the majority (95%) of the teachers said they did at least some of the time. When asked whether other teachers teach in this way, the majority (73%) clearly stated that other teachers do not. The reasons suggested for not teaching in the way they said they should were classified as either external or internal constraints (see Table 3).

TABLE 3
REASONS SCIENCE AND TECHNOLOGY IS NOT TAUGHT AS IT SHOULD

Internal	External
. Fear of a lack of control, noise	. A lack of time
. A lack of pedagogical knowledge	. Pressure from supervisors
. Fear of lack of knowledge in science and technology	. The need to follow school policies
. Fear of change and the temptation of the known	. Resources
. It is perceived as too hard.	. Children lack necessary skills
	. Community expectations
	. Formal testing.

The reasons imply that the teachers may have the following perceptions of science and technology education:

- Science and technology requires too much time to be taught appropriately and there are quicker ways than by using child centred approaches:

  > I try to teach the way it was said you should but sometimes I interfere with the "creative processes" of children because of time restraints - need to be somewhere else, eg. assembly...

- Child centred approaches which are appropriate for learning and teaching in science and technology result in classes which are noisy and make the teachers feel as though they have lost control. Some participants perceive executive members of staff as supervisors who are conservative and prefer traditional approaches:

  > ...because they feel they are not in control of the situation - children are noisy etc. Quite often neighbouring teachers/executive etc raise their eyebrows at the chaos... They prefer the organised quiet work approach.

- Science and technology should be taught in a particular way with a set content resulting in the development of scientifically and technologically acceptable knowledge:

  > ... because of stereotype images of what 'good' science teaching is about. What students must know and that incorrect knowledge should not be allowed.

- There is a tension between what teachers feel they should be doing in order to teach science and technology well, what they feel comfortable doing and the expectations of others as to what they should be doing. There is a general feeling that both the internal and external constraints reduce the amount of control teachers have over what they can do in their own classrooms. For example,

  > I do teach this way ... to some extent. There are external constraints placed on teachers which influence teaching style, eg, the school practices and policies,

> like having to follow set text books and having to prepare children for regular formal examinations.
>
> I try to teach this way but find it very tempting to revert to too much teacher input. I find it very difficult to work out appropriate activities. Some teachers.... find it difficult to move away from the traditional step by step - do it my way approach. Some teachers are not convinced that science and technology is really valuable. Many simply lack the confidence to start: that includes knowledge of physical science content but also the inquiry process.

CONCLUSION

The teachers involved in this research appear to have clear views about learning which are resistant to change and broadly consistent with modern views of learning. Their views emphasise the need for the learner to be motivated and allowed by the teacher to develop their own understandings. The views expressed about how to teach describe teaching in science and technology as occurring by a sequence of steps which occur before and after learning. Even these teachers who have been specifically targeted because of their commitment to science and technology education do not appear to have a clear view of how they should interact with children in order to promote learning. The two distinct views described of how teachers should teach, one which is 'child centred' the other teacher centred, suggest that their views of teaching are undergoing change or may represent differences between what they actually do and what they believe they should do. The teacher centred view of teaching was inconsistent with the views of learning which were described. Those teachers who commented on this contradiction were concerned by the mismatch between their beliefs and practices.

Alternatively, it may be that these teachers have no commitment to their stated views of learning and believe teacher centred models are the most effective strategies to bring about learning but such a conclusion is not supported by the journal entries. On the contrary, a picture of teachers committed to science and technology and a change in teaching emerges but, because they are unsure about exactly how they should teach they revert to familiar less desirable teacher centred strategies. For example,

> ...the preparation time is finite... consequently I take the 'easy way out' and opt for the directed approach. ... Maybe I'm a "closet chalk-n-talker" paying lip service to modern techniques and ideas? No perhaps that's too harsh. I am aware of change. I'm not comfortable...

Finally, apart from difficulties experienced in matching teaching strategies to beliefs about how children learn, teachers generally believe there are factors in schools which inhibit the implementation of good teaching practices. These include, supervision by executive staff, programs and assessment; the very things which should have, as their primary function, the enhancement of learning and teaching. These external influences require further investigation. In particular, to what extent is it merely a perception that these determine what individual teachers do in their classrooms and that they have little control over them?

The findings suggest that teachers do need opportunities to reflect on their beliefs of teaching and learning as these influence how they teach but they also have a need to develop strategies to promote learning; a need about which they themselves may not be clearly aware and one which is unlikely to be met solely through reflection. Attempts to bring about change need to also focus on the school as well as the individual teachers since each teacher seems to believe that a range of school based factors, over which they believe they have little control, may inhibit the introduction and implementation of teaching practices which they believe are appropriate.

REFERENCES

Briscoe, C. (1991). The dynamic interactions among beliefs, role metaphors and teaching practices: A case study of teacher change. Science Education, 75 (5), 185-199.

Clark, C.M. & Peterson, P.L. (1986). Teachers thought processes. In Wittrock, W.C. (ed) Handbook of research on teaching. New York: Macmillan.

Gallagher, J.J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. Science Education, 75 (1), 121-133.

Hewson, P. & Hewson, M.G. (1989). Analysis and use of a task for identifying conceptions of teaching science. Journal of Education for Teaching, 15 (3), 191-209.

Mitchener, C. & Anderson, R. (1989). Teachers' perspective: Developing and implementing an STS curriculum. Journal of Research in Science Teaching, 26 (4), 351-369.

Osborne, R. & Freyberg, P. (1985). Learning in science: The implications of children's science. Auckland: Heinemann.

Rennie, L. Parker, L. & Hutchinson, P. (1985). The effects of inservice training on teacher attitudes and primary school classroom climate. Research report. No 12. Perth: University of Western Australia.

Richardson, M. (1989). Teachers-as-learners: images from the past and implications of a (generative) constructivist perspective for the future. In J. Novak, (ed.) Proceedings of the Second International Seminar "Misconceptions and Educational Strategies in Science and Mathematics", Vol II. Ithaca: Cornell University.

Tobin, K. (1990) Changing metaphors and beliefs: a master switch for teaching? Theory into Practice, 29 (2), 122-127.

Tobin, K. & Fraser, B.J. (1987). Exemplary practice in science and mathematics education, Perth, Key Centre for School Science and Mathematics, Curtin University of Technology.

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PHYSICS TEACHERS' ACTION-RESEARCH EXPERIENCE WITH A TEACHING MODULE ON "FORCE"

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ABSTRACT

Eight physics teachers from three research schools working in collaboration with the author developed, tried, and evaluated a teaching module on "Force". The module was designed for students in a non- western society, for whom there is no cultural term that explicitly defines the concept. This paper describes illustrative examples of the trials and evaluation exercise of the module. It concludes with a summary of the effects the teachers' interaction with the module had on their professional development.

INTRODUCTION

A recent trend in science education has been the realization that students hold alternative conceptions of scientific phenomena. These misconceptions, as they are often called, are difficult to change, and are based on the students' everyday experiences of the world. The concept of force in physics is one of those phenomena about which students have alternative conceptions that are quite different from the scientific ones (Gilbert, Osborne & Fensham, 1982; Gilbert & Watts, 1983). However, Rowell, Dawson & Lyndon (1990) observed that while there has been a wealth of published research identifying misconceptions on the understanding of scientific concepts by students, relatively little has appeared detailing how these misconceptions can be rectified. Berg and Brouwer (1991) further state that one of the challenges facing today's researchers is to develop strategies for teachers' use in trying to correct students' alternative conceptions. The work reported in this paper was an attempt in that direction.

The paper describes a teaching module on Force designed for junior secondary school students in a non-western society (Sierra Leone), for whom there is no cultural word that explicitly defines the concept of force. The aim of the module was to help these students acquire the scientific understanding of the concept. The exercise was part of a study designed to investigate an educational change process through introducing science teachers to an innovative approach to teaching of physics at the junior secondary school level (ages 12-14). The sample comprised eight science teachers selected from three schools in Bo, Sierra Leone. The study began with an examination of these teachers' prior perceptions about the junior secondary school science programme. This was undertaken by means of interviews and classroom observations of the eight teachers, lasting for three months. A two-week in-service programme followed during which the teachers were introduced to the ideas of a constructivist-based science for all curriculum by the author (see Baimba, 1991). Subsequently, an action-research programme which involved these teachers working in collaboration with the author to develop, try, and evaluate teaching modules on Measurement and Force was undertaken. This paper describes the module on force together with illustrative examples of the action- research programme through its trials and evaluation.

SIERRA LEONIAN CONCEPTIONS OF FORCE

The laws of physics are expressed as relations between physical quantities. Force is a physical quantity and concept such as work and power are all related to it. Many examples of application of the knowledge of force exist in the Sierra Leonean traditional setting. These include lifting a load or drawing water from a well using pulleys, constructing stable structures such as houses and bridges, and balancing and carrying a load on the head.

In spite of these diverse applications, there is no Sierra Leonean word for the concept of force. The closest practical reference or suggestion of the concept is through action words such as rub, lift, compel, etc. which are regarded as complete ideas in themselves. In the Sierra Leonean mind these suggest no underlying abstract concept of force which is common to all. The aim of the module on Force was to highlight experiences that would help students studying the concept for the first time in a science lesson to:

- develop an understanding of the scientific meaning of the term 'force';
- identify and qualitatively describe different kinds of forces in everyday activities; and
- be familiar with some of the effects of common types of force.

MODULE

To achieve these aims, a teaching module was designed and patterned along the constructivist approach of teaching and learning science (Driver & Oldham, 1986). The module advises a teaching strategy comprising of four stages: exploration of students' ideas, development of the concept, application of the learned concept, and evaluation (see Figure 1.)

ACTION-RESEARCH TRIALS AND EVALUATION OF THE MODULE

The module was taught in four sessions: two double periods of 80 minutes duration and two single periods of 40 minutes duration in any one particular stream. One teacher from each of the three research schools, was assigned two streams of Form 2 students. This was to facilitate the trials and retrials of teaching units of the module by the same teacher on different streams of students. Using the module, weekly lesson plans were developed by individual teachers. The action-research consisted of a cyclic process of trial - evaluation - modification and retrial of the respective lesson plans.

The trial exercise was monitored by the author and the heads of the science departments from the three research schools through classroom observations and interviewing. The interviews were of two types. There were after-lesson interviews during which the author and the particular teacher jointly evaluated the lesson, often leading to modifications in subsequent lesson plans for retrial. Also, regular weekend meetings were held during which the author and teachers co-planned work for the following week. The following section illustrates proceedings of some of the trial lessons.

FORCE

Stage	What?	Why?	How?
1.	EXPLORATION	To establish sense of purpose for studying Force and solicit students' prior ideas on this concept.	Brainstorming.
	FOCUSING	To arouse students' interest in studying a topic in Force.	Use everyday examples to emphasise the importance of knowledge of Force, e.g., ask for students' explanations of the following phenomena: Why do objects fall when they are released from a height above the ground? Why should vehicles slow down when negotiating curves?
	ELICITATION OF STUDENTS' PRIOR IDEAS	To encourage student to reflect on their prior frame-works on the concept and make these frame-works public.	(a) Use students' explanations for the above phenomena to capture the key word - FORCE. (b) Solicit students' understanding of the term Force, and examples of types of forces with which they are familiar.
2.	DEVELOPMENT OF THE CONCEPT	To clarify and modify students' conceptions of Force.	Present students with the scientific conception of Force.
	CLARIFICATION	To clarify and modify students' ideas (or misconceptions) about the concept.	Present students with selected frame-work of forces in action: reaction forces on objects at rest; tension forces in pulling objects; friction forces in opposing motion; magnetic force in producing motion. Encourage students to describe how these frameworks agree or disagree with their prior conceptions.
	FORMALIZATION OF STUDENTS' IDEAS	To acquaint students with the scientific meaning of Force, some examples of kinds of forces, and qualitative account of the uses and effects of some of these forces.	Use the above examples to teach students the scientific frame-work of Force. Rectify students' classification of examples of kinds of force, and help them explain in their own words the meaning of some of these forces (e.g., gravitational, frictional and reactional). Organize activities to demonstrate the effects of common types of forces (e.g., gravity, magnetic and frictional). Provide students with qualitative explanation of the uses and effects of some common types of forces (e.g., frictional forces enable us to walk, but they can also cause wear and tear on objects. Centripetal forces keep objects moving in a circle, but are dangerous when a fast moving object moving in a straight line approaches a curve).
3.	APPLICATION	To consolidate and reinforce the newly learned concept.	Engage students in small projects such as identifying kind of forces in action in their communities. For example naming the kinds of forces involved with: a hanging hammock; drawing water from a well; tug of war; and walking. Encourage students to identify areas in which the principle of force is applied in their communities.
4.	EVALUATION	To test students' understanding of the unit on Force.	Through classroom questioning, assignments, small projects and formal tests. Check whether students: understand the scientific conception of Force; can identify and describe examples of kinds of forces common in their localities; can offer qualitative scientific explanations for common phenomena applying principles of force.

Fig. 1. Instructional guide for the teaching package on Force

Lesson 1

The aim of the first lesson was to establish the importance of studying a unit on 'force', and solicit students' prior conceptions on the topic. To introduce the lesson, one of the experimental teachers engaged students in the following dialogue:

Teacher: Who can tell me why people are not allowed to drive vehicles with smooth tyres?
Pupil: Because the police will arrest them.
Teacher: Why will the police arrest them?
Pupils: (No response)
Teacher: Has any of you tried to walk on a polished floor?
Pupils(Chorus) Yes
Teacher: Is it difficult or easy?
Pupils(Chorus) It is difficult
Teacher: Why is it difficult?
Pupil: It is slippery?
Teacher: Why is it difficult to walk on a slippery surface?
Pupils: (No response)

At that point, the teacher wrote the word Force on the board and continued the conversation as follows:

Teacher: Who can pronounce the word on the board?
Pupils(Chorus) Force
Teacher: Have you come across that word before?
Pupils(Chorus) Yes
Teacher: What does it mean?
Pupil 1: Force is when you force somebody to do something.
Pupil 2: Force is the energy we apply to something that makes it move.
Teacher: Any other meanings?
Pupils: (No response)
Teacher: Can you give me examples of Force?
Pupil 1: Police force
Pupil 2: Military force
Pupil 3: U.S. Navy
Pupil 4: Force of gravity

The teacher summed up the lesson by informing the students that they would continue the discussion in the next lesson to find out the scientific meaning and examples of force.

Lessons 2 and 3

Lessons 2 and 3 were practical classes aimed at familiarising students with examples of scientific frameworks for force. To enable them to conceptualize the scientific meaning of the term, students were engaged in activities that illustrated examples of common types of forces - gravitational, reaction, tension, magnetic and frictional. An example of the type of activities the students were engaged in is reproduced below.

Materials: Nails, sizeable stones, strings, clamps, wooden blocks, pulleys and scale pans.

Instructions: Use the materials provided to do the following exercises:

> Tie a piece of string around the stone. Hold it in the air by holding onto the end of the string. Does the stone fall? If no, explain what stops it from falling. If yes, explain why it falls.
>
> Use a piece of string to tie the wooden block to the pulley. With the wooden block resting on the table, pass the connecting string over a pulley clamped at the edge of the table so that the scale pan hangs freely in air. Add the stones provided one at a time into the scale pan. Does the scale pan or the wooden block move? Explain what is stopping the scale pan and its contents from falling? What will happen to the scale pan and its content if you cut the string midway between the scale pan and the wooden block? Explain.

At the end of Lesson 3, the teachers utilized the results of the practical exercises to present students with scientific frameworks of force and examples of the common types of forces.

All experimental teachers expressed satisfaction with the students' participation in the practical activities in Lesson 2. However, two problems emerged that were common across the three research schools. Firstly, students from the three schools displayed lack of understanding of the concept of weight for bodies in equilibrium. For example, students in all three schools knew that a stone let free in the air fell because of the "pull of gravity on the stone". But when that same stone was suspended in the air by tying a string around it, the students' understanding of 'pull of gravity' became obscured. In that new frame, they could not tell what had happened to the pull of gravity because the stone no longer fell.

The following conversation between a particular experimental teacher and his class clearly depicts that problem:

T: What causes the stone to fall?
P: The force pulls the stone towards the earth.
P: The force pulls the stone.
T: How do we call this type of force which causes objects to fall towards the earth?
P: Gravitational force.
T: What generally makes things fall?
P: Their weight
T: Why does the stone not fall when I suspend it in the air by means of the string?
P: It is being stopped by something.
T: Who can tell me what that something is?
(No response)
T: Is the weight of the object still acting on it?
(No response)

The other problem was that the students tended to associate force with motion. In the exercise involving the wooden block and the scale pan, students consistently denied action of any force(s) on the scale pan as long as the wooden block remained stationary. Similarly, when asked if a student pushing a wall was applying force, the answers in all classes consisted of "Yes" and "No". Those who answered "No", on each occasion, argued that there was no force because the walls were not moving. Because of these problems, the original lesson plan of each trial teacher was modified by allocating more time to explaining the concept of weight to the students. Also, a game of tug-of-war was included as one of the class activities to help students internalize the possible frameworks that two forces acting in opposite directions could generate.

Despite the additional time spent revising the concept, students' difficulties in relating weight to other forces acting on bodies in equilibrium (e.g., a book resting on a table or an electric bulb suspended by a flex in the ceiling) persisted. On the other hand, all experimental teachers in the three research schools told the author that the tug-of-war exercise helped students to gain better understanding of the ideas that two forces acting in opposite directions might (or might not) produce motion depending on their magnitudes, and that the absence of motion did not necessarily mean the absence of force(s) in action. There might be opposition such as one team of the tug-of-war resisting being pulled by the other team.

Lesson 4

In Lesson 4 students were taught simple explanations for some everyday phenomena involving an understanding of the concept of force. Even though students from the three research schools were familiar with the examples selected by their respective teachers, it was only in one school that scientific explanations for some of the examples were offered by the students. Nevertheless, students from the three schools showed great enthusiasm in this lesson, possibly because they could relate what they were learning to real life situations.

EFFECTS OF THE EXPERIENCE ON THE PARTICIPATING TEACHERS.

The major impact of the exercise on the experimental teachers concerned change in their outlook about the image of the junior secondary school science programme. During one of the after-trial interviews with the author, one of the teachers stated: "I never had clear ideas about the aims and objectives of general science curriculum. I only learnt that through participation in this study". Another teacher informed the author: "We found out that students have ideas about science even though some of these ideas are vague". The problem according to this teacher was that: "Students cannot explain these ideas and science teachers had in the past not related students' experiences to their lessons".

Another outcome of the study was the teachers' ability to develop teaching units using local resources. One teacher reported that in the past he had used textbook examples which were unfamiliar to both himself and his students to describe scientific processes in general science classes. Yet he acknowledged not using any textbook to draw up his lesson plans from the module. Apart from the advantage of making the case study teachers less dependent on textbooks, grounding the module in real life examples also minimized these teachers' total dependence on stereotyped laboratory sessions for science practicals. They reported that they did not need laboratories per se to teach the module, and that the environment provided them with sufficient material to engage students in practical activities. They stressed this particular aspect of the module as an important feature since many of their colleagues believed that science practicals could only be thought of as laboratory sessions.

Another positive outcome of the teachers' interaction with the module was the teachers' image of themselves as co-researchers. It became evident that the experimental teachers regarded themselves as researchers rather than just recipients or 'triers' of the author's ideas. Phrases like "our work, the curriculum we have developed, our new curriculum", were identified as common descriptors the experimental teachers used to refer to the new teaching packages. This is an important outcome, because even though teacher participation in curriculum development is widely advocated, the ideas are rarely implemented in many developing countries. It also became apparent that the experimental teachers' understanding of the aims and objectives of the general science curriculum in general, as well as the nature and ways of acquiring scientific knowledge, were enhanced following interaction with the module. In particular, the conceptual change approach that was employed in the trials of the module appealed to them as a better method of teaching science. The approach enabled them to come to terms with the idea that students had their own understanding about the concept of force even though the ideas could be classified as lay and/or gut science (Claxton, 1984). According to these teachers, recognition of students' prior ideas enabled them to rectify students' misconceptions.

SUMMARY

This paper has presented illustrative examples of the action-research trials of the module. The results support available literature that students' conceptions of force are at times contrary to scientific ones. The citing by Sierra Leonean students of 'police', and 'military' as examples of force in physics illustrated the point. The effect on the professional development of the experimental teachers' interaction with the module supports finding by Bonnstetter and Kyle (1986) that a well articulated in-service education programme enables teachers to portray a much more positive and exciting image of science. Nonetheless, the trial exercise was marked by difficulties that are common to curriculum innovation programmes (e.g., teachers' readiness to give practical expression to their theoretical understanding of the change process). Techniques employed to overcome this problem suggest that the establishment of conceptual clarity for the meaning of the innovation appeared to be the essential factor in arousing the experimental teachers' commitment. In this study, preliminary interview results brought vivid realisations upon the experimental teachers about how divorced school science was from the everyday experience of their students. This led to their willingness to participate in innovative curriculum research aimed at making knowledge of school science more functional for their students.

REFERENCES

Baimba, A.A. (1991). Innovation in science curriculum: A Sierra Leone case study. D.Phil thesis, University of Waikato.

Berg, T. & Brouwer, W. (1991). Teachers' awareness of students alternate conceptions about rotational motion and gravity. Journal of Research in Science Teaching, 28 (1), 3-18.

Bonnstetter, R.J. & Kyle, W.C. (1986). A longitudinal assessment of students' and teachers' attitudes towards science in process versus traditional science classes. ERIC Document Reproduction Services No ED 270330.

Claxton, G.L. (1984). Live and learn. London: University of London Press.

Driver, R. & Oldham, V (1986). A constructivist approach to curriculum development in science. Studies in Science Education, 13, 105-122.

Gilbert, J.K., Osborne, R.J. & Fensham, P.J. (1982). Children's science and its consequences for teaching. Science Education, 64 (4), 623-633.

Gilbert, J.K. & Watts, D.M. (1983). Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. Studies in Science Education, 10, 61-98.

Rowell, J.A, Dawson, C.J & Lyndon, H. (1990). Changing misconceptions: A challenge to science educators. International Journal of Science Education, 12 (2), 167-175.

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LEARNING IN INTERACTIVE SCIENCE CENTRES

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ABSTRACT

The potential of informal sources of science learning to supplement and interact with formal classroom science is receiving increasing recognition and attention in the research literature. In this study, a phenomenographic approach was used to determine changes in levels of understanding of 27 grade 7 primary school children as a result of a visit to an interactive science centre. The results showed that most students did change their levels of understanding of aspects of the concept "sound". The study also provides information which will be of assistance to teachers on the levels of understanding displayed by students on this concept.

INTRODUCTION

It is being increasingly recognised that children's science learning occurs from a variety of sources outside the classroom and that these learning sources have the potential to interact with classroom science learning (Schibeci, 1989; Wellington, 1991). Formal science learning in classrooms is distinguished from informal science learning by authors in different ways (Lucas, 1983; Maarshalt, 1988). A further distinction is made between intentional and unintentional sources of informal science learning, it being seen as intentional when the aim is to teach as in museums and interactive science centres and unintentional as in television programs, fiction and other media such as newspapers (Lucas, 1983). Others refer to interactive science centres and museums as nonformal sources of science learning and the discussion that occurs outside the classroom about the science that is discussed in classrooms as informal science learning (Maarshalt, 1988).

One of the success stories of the last decade has been in the growing interest in and increasing number of interactive science centres established as places of public learning. Early criticisms of such centres were that they constituted places of fun and entertainment but that very little learning was believed to occur (Shortland, 1987). Further studies showed that visitors approached science centres with a variety of intentions including the intentions to enjoy, to learn and to have a family outing, so that the intention of the visitor was also an important factor in whether learning occurred (Lucas, McManus & Thomas, 1986).

Studies on interactive science centres have shown that the intellectual involvement of participants increases with hands on involvement (Koran, Morrison, Koran & Gangara, 1984; Blud, 1990), that they develop positive attitudes to science and they that are enjoyable experiences (Feher, 1990; McManus, 1985). Previous studies have also shown that some learning does occur during interactive science centre visits (Russell, 1990; Tuckey, 1992; Wellington, 1991) but that there is still a need for further studies to investigate the increase in understanding resulting from such visits (Finley, Lawrenz & Heller, 1992; Russell, 1990). Also, many of these studies employed traditional testing instruments which only categorise learning and understanding dichotomously, rather than on a continuum showing different levels of understanding (White & Gunstone, 1992). Further, Wellington (1991) considers it "surprising that children's informal science learning in science, with its acknowledged influence on pupils and its potential for classroom enrichment, remains a relatively under-valued and under-researched area" (p 364).

The present study investigated the change in understanding of aspects of the concept "sound" that occurred as a result of a visit by primary school students to an interactive science centre. The objectives were to investigate the levels of understanding of aspects of the concept "sound" held by grade 7 students, and to investigate the change in understanding that occurred in these levels of understanding as a result of a visit to an interactive science centre.

METHOD

The sample consisted of 27 grade 7 students (14 boys and 13 girls) randomly selected from two classes of a suburban Brisbane primary school. Practice was given in drawing concept maps (including the concept of "sound") over several weeks before the study began to reduce practice effects during the study. Children were assessed on their understanding of this concept approximately one week before the visit to the interactive science centre by a structured interview and by their drawing of a concept map.

The science centre featured a whole floor of 13 exhibits dedicated to this concept. These exhibits involved the five aspects of sound as shown in Table 1. The interview was based around these aspects of the concept and stimuli were selected so as to provide the students with an opportunity to display their levels of understanding relating to them. The stimuli selected are also reported in Table 1. Pen and paper were available and hand gestures, as for example in the description of waves, were also noted. The interviews were audiotaped and transcribed. The children visited the centre for 75 minutes. They interacted with the exhibits in pairs with freedom to explore in any order. While this is acknowledged as a limited exposure to the exhibits, it represents the typical time allocation most students would receive to see such a set of exhibits when visiting with their primary school class. One week after the visit to the science centre, the children redrew a concept map and were again interviewed using the same stimuli to assess their understanding of this concept.

ANALYSIS AND RESULTS

Phenomenography is a qualitative research method which is concerned with "discerning and describing the qualitatively different ways people experience the world " (Marton, 1981). It involves recording the responses to questions about a concept and dividing those responses into the qualitatively different ways in which it is conceptualised. These conceptions are termed categories of description (Marton, 1981; Marton & Saljo, 1984) and are not predetermined but created as a result of examination of the interview protocols (Van Rossum & Shenk, 1984; Johansson, Marton & Svensson, 1985). The method rests on the assumption that there are a limited number of categories that students use in conjunction with particular concepts (Johansson et al., 1985; Marton, 1988).

Categories were determined from the interview data using an interpretive nonalgorithmic method (Marton & Saljo, 1984). In this preliminary analysis, the most parsimonious result was to develop one set of categories for the production of sound and another for the transmission of sound. The resulting categories of description are reported in Table 2 along with some explanatory examples of the kinds of responses typical of particular categories.

TABLE 1
STIMULI FOR INTERVIEWS AND RELATED EXHIBITS IN SCIENCE CENTRE

	INTERVIEW	SCIENCE CENTRE EXHIBITS
A	Production of sound	
1	Vibrations and waves Cue cards with photos of trombone and guitar	Tea Chest Bass, Seeing Pressure Waves, Seeing Sound, Favourite Frequencies
2	Volume and Pitch A recorder to play notes of different pitch and colume	Harmonics, Thongaphone, Pipes of Pan, Tea Chest Bass, Tone Memory
B	Transmission of sound	
1	Reflection and direction of transmission Researcher turns away and speaks, refers to noise from outside the room	Echo Tube, Focussed Sound, Stereo Hearing, Tube Memory
2	Transmission through a medium Cue cards with one member of party with ear to railway line/ground reporting approaching train/horses	Echo Tube, Pressure Waves
3	No transmission in a vacuum Cue cards depicting supernova explosion in space; and persons talking on the moon.	Bell in a vacuum apparatus.

After the researchers had determined the categories, two science teachers and the researchers independently assigned each student to a category for each stimulus representing the level of understanding displayed in their responses. This was carried out separately for the previsit and postvisit interview. Concept maps were also inspected to assist in assigning students to categories of description. Interjudge reliability (Johansson et al., 1985) was over 90% and differences were resolved by further discussion.

In this study, learning is defined as a change between qualitatively different conceptions (or categories of description) between the pretest and posttest (Johansson et al., 1985). Assessed in this way, the study will reveal changes in levels of understanding even if that level is not consistent with the currently held scientific view.

Table 3 reports examples of the changes in the categories of description for four students showing a range of change between the pretest and posttest. Only five of the 27 students failed to show a change between the pretest and posttest in the category of description describing their level of understanding of one or more of the five subtopics in Table 1. The level of understanding of volume and pitch for some students underwent major changes (for example students A and B in Table 3), some students even correctly associating amplitude and wavelength (described in their own way) with

TABLE 2
CATEGORIES OF DESCRIPTION AND EXAMPLE RESPONSES#

*	Explains production of sound(s) in terms of:
P1	Descriptions of the actions or correlates that produced the sounds; e.g. different holes were covered with the fingers on the recorder, differing lengths of guitar string were used, the air had to travel different distances in the trombone, the amount of air used to produce the sound(s) was different.
P2	Sound as vibrations or waves; due to vibrations or waves in the guitar strings or trombone and could give some indication of the nature of a vibration or wave.
P3	Different sounds as due to different characteristics of the waves or vibrations; knew that different sounds were due to differing characteristics but without an awareness of how they differed.
P4	Differences in the amplitude and wavelength of waves or vibrations; described different sounds as due to differences in their wavelength and amplitude (using their own terms and often illustrated by drawing in the air) but not correctly associating amplitude and pitch with these characteristics.
P5	Differences in the amplitude and wavelength of vibrations or waves and correctly associating with volume and pitch of sounds.
*	Explains transmission of sound(s) in terms of:
T1	Attributions of a property of other materials or phenomena; sound goes through the wall like a ghost, only through the cracks in the wall, no gravity to pull the sound down to the earth.
T2	Line of sight transmission; can not hear sounds from other side of building or over the hill as these situations stop the sound from reaching the listener.
T3	Decrease in the intensity of sound with distance; you can not hear sounds from space on earth because they are too far away to hear.
T4	Promulgation in all directions and reflection from solid objects such as walls; the sound vibrations when we speak go all around us and bounce off the walls.
T5	Different media having different properties of sound transmission; can hear oncoming train with ear to rail because sound vibrations travel better through the rails than through air.
T6	Transmission of sound requires a medium; sound can not be heard from space because there is no air to carry it.

No distinction is made for these students between transverse and longitudinal waves.

variations in volume and pitch. This understanding did not always transfer to explaining how the trombone (in particular) and the guitar produced sounds and students were more likely to discuss sounds from the guitar in terms of vibrations than they were for trombone sounds. A common explanation of the different sounds from the guitar was in terms of the vibrations having different distances to travel down the guitar string before they enter the hole where the sound was produced. Students in which these major changes occurred would often refer to particular science centre exhibits which visually displayed sound waves. Similarly, where children changed their understanding of the reason why sound was not transmitted in space to the correct scientific view, they often referred to the bell in the vacuum exhibit. On the other hand, student C who did not display any change in his level of understanding of this concept was unable to recall that exhibit as relevant. Most students were aware that sound could be reflected off walls and other solid objects and that it was promulgated in all directions.

TABLE 3
EXAMPLES OF CHANGES IN LEVELS OF UNDERSTANDING FROM PRETEST TO POSTTEST *

Student/ Testing	Interview Stimulus					
	Pitch/ Volume	Trombone	Guitar	Reflection	Different Mediums	Space
Student A:						
Pretest	P2	P2	P2	T4	T5	T6
Posttest	P5	P4	P4	T4	T5	T6
Student B:						
Pretest	P1	P1	P2	T4	T5	T3
Posttest	P4	P4	P4	T4	T5	T6
Student C:						
Pretest	P1	P1	P2	T1	T2	T1
Posttest	P3	P1	P2	T4	T2	T1
Student D:						
Pretest	P2	P1	P2	T4	T2	T1
Posttest	P2	P1	P2	T4	T2	T3

* Table entries refer to categories of description in Table 2

DISCUSSION

A prominent feature of research on children's learning in science has been the important role of the prior knowledge that they bring to the learning situation. A study of the changes in the levels of understanding relating to the production of sounds shows that students who already had the concept of sound as a vibration or wave were most likely to have made major changes in their levels of understanding towards the scientifically accepted view relating amplitude and wavelength to different sounds. This is consistent with the view of that while exhibits can enhance understanding, they are less likely to teach unfamiliar concepts (Tuckey, 1992). Further, as the concept of sound is included in primary and secondary curricula, the documentation of the levels of understanding that students bring to further studies relating to this concept will be a valuable resource for teachers.

Wellington (1991) has discussed how informal science learning may both inhibit and facilitate formal science classroom learning. The interviews showed that the cognitive structures of students after the visit to the science centre included images and episodes (Gagne & White, 1978) relating to the exhibits which they regularly drew on in providing their explanations of phenomena. The most commonly mentioned exhibits were those related to the bell in the bell jar, display of sound waves electronically and as standing waves in a liquid, and the focus and transmission of sound by large reflectors. Clearly, these images and episodes could be readily referred to and would enrich the formal classroom teaching of this concept. On the other hand, in science centres as in other sources of learning students often interpret their observations in unintended ways (Feher, 1990). For example, one student interpreted his inability to hear the bell when the bell jar was evacuated in terms of the returning air causing the bell to ring.

While the changes in the level of understanding as a result of the visit to the science centre varied from student to student and from aspect to aspect of the concept under study, it is concluded that for most students the visit was a worthwhile experience in that it enhanced their understanding of the concept sound. This research provides further support for the potential of science learning from informal sources to interact with formal learning in classrooms to enrich and enhance science learning.

REFERENCES

Blud, L. M. (1990). Social interaction and learning among family groups visiting a museum. Museum Management and Curatorship, 9, 43-51.

Feher, E. (1990). Interactive museum exhibits as tools for learning: Explorations with light. International Journal of Science Education, 12(1), 35-49.

Finley, F., Lawrenz, F., & Heller, P. (1992). A summary of research in science education - 1990. Science Education, 76(3), 239-338.

Gagne, R., & White, R. (1978). Memory structures and learning outcomes. Review of Educational Research, 48, 187-222.

Johansson, B., Marton, F., & Svensson, L. (1985). An approach to describing learning as change between qualitatively different conceptions. In L. H. T. West & A. Leon Pines (Eds.), Cognitive structure and conceptual change. London: Academic Press.

Koran, J. J., Morrison, L., Koran, J., & Gangara, L. (1984). Attention and curiosity in museums. Journal of Research in Science Teaching, 21(4), 357-363.

Lucas, A. M. (1983). Scientific literacy and informal learning. Studies in Science Education, 10, 1-36.

Lucas, A. M., McManus, P. M., & Thomas, G. (1986). Investigating learning from informal sources: Listening to conversations and observing play in science museums. European Journal of Science Education, 8(4), 341-352.

Maarshalt, J. (1988). Scientific literacy and informal science teaching. Journal of Research in Science Teaching, 25(2), 135-146.

Marton, F. (1981). Phenomenography - describing conceptions of the world around us. Instructional Science, 10, 120-170.

Marton, F. (1988). Phenomenography, exploring different conceptions of reality. In D. M. Fetterman (Ed.), Qualitative approaches to evaluation in education. London: Praeger.

Marton, F., & Saljo, R. (1984). Approaches to learning. In F. Marton, D. Hounsell, & N. J. Entwistle (Eds.), The experience of learning. Edinburgh: Scottish Academic Press.

McManus, P. (1985). Worksheet induced behavior in the British Museum (Natural History). Journal of Biological Education, 19(3), 237-242.

Russell, I. (1990). Visiting a science centre: What's on offer. Physics Education, 25, 258-262.

Schibeci, R. A. (1989). Home, school and peer group influences on student attitudes and achievement in science. Science Education, 73(1), 13-24.

Shortland, M. (1987). No business like showbusiness. Nature, 6, 213-214.

Tuckey, C. (1992). Children's informal learning at an interactive science centre. International Journal of Science Education, 14, 273-278.

Van Rossum, E. J., & Shenk, S. M. (1984). The relationship between learning conception, study strategy and learning outcome. British Journal of Educational Psychology, 54, 73-83.

Wellington, J. (1991). Newspaper science, school science: Friends or enemies? International Journal of Science Education, 13(4), 363-372.

White R., & Gunstone, R. (1992). Probing understanding London: The Falmer Press.

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PROGRESSION IN LEARNING SCIENCE

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ABSTRACT

A national curriculum comprising statements of attainment at different levels must be underpinned by some idea of "progression" in learning. Questions arise as to the nature and meaning of progression. To gain a deeper insight into how children progress in their understanding of science, this research involves the construction and testing of a hypothetical learning sequence for the topic of forces. This interim report explains how children aged 7 to 13 are being interviewed to explore their explanations of phenomena involving forces. These explanations will be mapped onto the sequence to provide a multi-dimensional model of progression.

INTRODUCTION

In the national curriculum for England and Wales, each subject is specified in terms of a few main target areas, each covering the whole range of compulsory schooling from ages 5 to 16. All target areas are specified by criterion statements set in a sequence of ten levels, level two comprising criteria appropriate for the average 7 - year old, level three for a 9 - year old, and so on. This system follows a recommendation (DES, 1988) that the curriculum should promote a criterion referenced approach which would support formative assessment and serve as a guide to the progression in learning of each child. Pupils would be expected to progress at different rates through the ten levels.

This scheme requires that the criterion statements are grouped in appropriate levels and ordered in an appropriate sequence. Whilst those writing the curriculum have done this as best they can, this demand gives rise to fundamental questions about progression in learning and about the effects of teaching on such progression. As Driver (1989) points out, studies of students' conceptions present us with discrete snapshots in the continual construction and reconstruction of students' knowledge. Although such studies provide valuable insights that can inform curriculum planning and the possible sequencing of ideas for teaching purposes, they do not provide information on the dynamics of change, information that is necessary as a basis for understanding progression, and designing curricula in a progression framework.

This paper reports on the first stage of a two-year project which aims to study progression in children's learning of two topics. Of these two, measurement and forces, only the second will be discussed. The discussion is based on preliminary findings and concentrates on describing theoretical and methodological issues.

DESIGN OF THE STUDY

The data for the study are being collected by individual interviews, each interview being based on phenomena shown to the child with simple equipment. Children at ages 7, 9, 11 and 13 were selected, with six pupils chosen from each of three schools at each age. It is intended that each of these seventy-two children will be interviewed on two occasions, about three months apart, so chosen that teaching relevant to the interview topics will have taken place between the two occasions. There has been no attempt to do other than observe this teaching as carried out by each teacher in his or her normal way. The interview structure and the equipment and effects to be used were developed and refined through pilot studies. At the time of writing, most of the interviews for the first of the two main occasions have been completed, but the analysis of the interview transcripts is only just beginning.

Looking for progression in learning

The basis for the approach may be explained by a pictorial metaphor (see Figure 1). There are two countries, the science country inhabited by scientists and science teachers, and the pupils' country. The ways of thinking and the ideas used in these two countries are very different. The task of a research may be seen as an exploration of both countries which might lead to a comparison between the two and so to a study of ways of crossing the bridge. What constitutes crossing the bridge will differ according to the theoretical perspective employed.

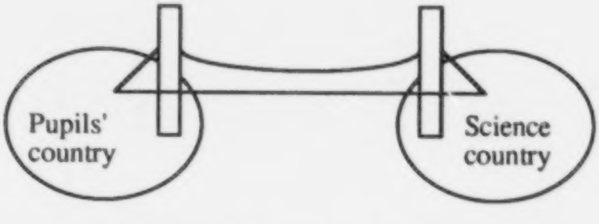

Fig. 1 The pupils' country and the science country

Moreover, any research faces the methodological problem of deciding the basis on which its exploratory tools are to be constructed. The simplest way is to use the schemas of science to guide the construction of these tools. This has the advantage that the information gained will be directly related to the aims of the teaching, but the disadvantage that the pupils' world is being seen only through the selective, and possibly distorting spectacles, of the science country. Most research studies of alternative conceptions adopt this approach, although the research reports rarely discuss the rationale underlying the selection and composition of the research instruments used.

A second approach is to treat the pupils' country as a separate world to be explored on its own terms. This is attractive because it might give a more authentic view of the problem of constructing the bridge. However it is much harder to do because there is no obvious way of starting if one wishes to avoid causing bias in the data by using pre-conceived views. The proposal of the "naive physics manifesto" by Hayes (1979), and the work of Bliss, Ogborn and Whitelock (1989) on "common sense understanding" are examples of a direct approach of this type. Others have made more general proposals about the nature of the thinking peculiar to the pupils' world. Examples are Andersson's "experiential gestalt of causation" (1986), Carey's accounts of the nature of children's theorising (1989), Claxton's mini-theories (1991), Di Sessa's p-prims (1983) and Solomon's (1983) concept of a "life-world" separate from the "science-world".

For the purpose of the present research, the second approach has not been used in the development of the interview methods. However, although the examples and the questioning of the pupils have been based on a scientist's analysis of the problems involved, it seems possible that by careful attention to pupils' responses in interviews, and particularly by carefully following up unusual or bizarre statements, some evidence about the pupils' country might be obtained and analysed.

Progression and conceptual change

The aim of describing progression raises first of all the problems of conceptual change. The approaches to this issue in research to date have been mainly pragmatic in nature (Scott, Asoko & Driver, 1992) rather than linked to or derived from a theory of cognition. Some aim to create dissatisfaction of the pupils with their own country, an approach which risks doing more harm than good with the less able and less confident pupils. Others stress a search for continuity to achieve more gradual change. Clement, Brown and Zietsman (1989) have explored this approach, emphasising the value of seeking out "anchoring conceptions" - ideas in the pupils' country which happen to be similar to those of the science country - and working by developing these as a base from which to lead the pupils into the new country.

White and Gunstone (1989) emphasise that it is unlikely that pupils will abandon their ways of dealing with the world simply because of ideas about a few problems established in science lessons. Indeed, adult scientists do not use their science thinking to deal with all aspects of their lives, but only deploy it in those particular contexts where they judge it to be more effective than their everyday common-sense thinking. Pupils also limit their use of science thinking —to the contexts of school science lessons. It would be unreasonable to expect them to do more —but what pupils need to understand is that they are deploying these two different approaches to reasoning about natural phenomena and that they need to take the new one both as seriously different and as a potential for understanding a wider range of contexts than those in which they have learnt about it. In this view, emphasis is therefore to be placed on meta-cognition as an aim in science teaching. However, whilst it may be true that such meta-learning is a helpful, perhaps necessary, condition for pupils to develop scientific learning, it cannot be a sufficient condition, for they will still need to develop the scientific reasoning of which they might now be more clearly aware.

Most of the literature cited above has little to say about the general issue of progression, being concerned to report on pupils work with particular ideas at a particular stage. A few have set out to put pupils' ideas in a sequence of hypothesised transition from their own to the scientific ideas, but attempts to test these hypotheses by looking for correlations in the structure of pupils' ideas or by longitudinal study of the progress of a cohort of pupils are notably absent (see however Denvir & Brown, 1986).

The problem of progression has several aspects. One would arise by asking what sequences of learning actually take take place in the pupils' own country over time, quite irrespective of any influences of science teaching. A second aspect is to explore how the learning that pupils do achieve through science teaching develops in time. These two might be intertwined, for it is at least possible that, for example, pupils at age 7 might come to grasp a science idea in manner different from pupils introduced to the same idea for the first time at age 13. In addition, although there may be an optimum way in which pupils might progress across the bridge between the two worlds, they might follow different sequences in response to the different ways in which they might meet science ideas in different teaching approaches.

To sum up, the proposal to explore progression is hampered both by the lack of an effective theory of conceptual change and by the absence of substantial evidence about the changes in pupils ideas with time. Ideally, data to strengthen the empirical base ought to be based on studies of several cohorts of pupils, each followed over several years, starting at several ages, and closely linked to studies of teaching programmes. The present study is very limited by comparison; any interpretation of its data must pay careful attention to these limitations.

Design of the items

There were two main aspects to the development of the test items:

- the science concepts to be explored; and
- the kind of situations which would best serve to stimulate and explore children's thinking

Decisions about which science concepts to explore were made by reviewing the forces domain to identify key concepts, and by reviewing previous studies to see what was known about children's understanding of this domain. The numerous studies about children's conceptions (Pfundt & Duit, 1991) provide information about conceptions of motion, gravity, and Newton's Third Law.

Decisions about ways of probing understanding were made by reviewing the methods of previous studies. Interview methods of probing understanding have been employed in many studies in recent years, some of which have been in the science domain of forces (Gunstone & White, 1980; Osborne & Gilbert, 1980). Studies using interviews about instances or events reveal many insights about children's thinking.

We decided to use interviews about events to probe children's understanding of forces in equilibrium. Analysis of the literature and preliminary pilot interviews showed clearly that a detailed understanding in both of the areas of equilibrium and of motion would be too demanding. Equilibrium was chosen for the following, interrelated reasons: it seemed easier to produce practical examples in interview; it seemed easier to set up different but related contexts in which several different types of force are involved; it is logically prior to motion in any schema for forces; and it had been less thoroughly explored in the reported research.

We tried out interviews about instances using diagrams which had been employed previously in other studies of children's understanding of force (Osborne & Gilbert, 1980). We found that to probe for understanding, more fruitful questions could be asked if equipment was used to show real phenomena. Also, children responded more readily if they could see something happening, particularly younger children.

Three test situations were developed which enabled us to explore children's understanding of force in different contexts. These situations are referred to as "Weight", "Hanging box" and "Bridges" and are illustrated in Figures 2(a), 2(b) and 2(c) respectively.

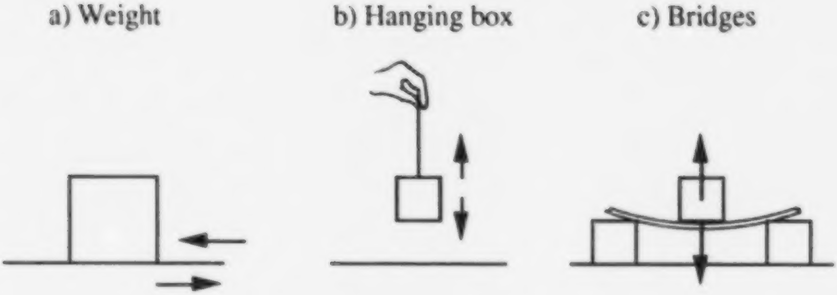

Fig. 2 Three test situations

Weight Children were provided with a 1kg mass and different surfaces on which to push and pull it, including a table top, wood, and sandpaper. The forces involved here were friction and a human push. The different surfaces allowed the friction to be varied. A change from equilibrium to motion was evident.

Hanging box Children were given a box attached to two elastic bands and a loop of string. The box contained a few stones and could be lifted by pulling up one band, two bands, or the string. The forces involved were gravity, the force arising from distortion (stretching) of the elastic or string and the human pull. The distortion force could be varied, by using different bands and the string. The elastic could be raised gradually so that its stretch increased with the box resting on a table until it lifted the box off the surface. Emphasis was on equilibrium, although this could be disturbed by pulling the weight down so that it shot up when released and oscillated vertically.

Bridges Children were shown two bricks, a piece of thick card and a box containing a 400g mass. A bridge was built with the bricks and card, and the box placed on the top. Other bridges were built using a thinner piece of card, and an identical box containing a 600g mass. The lighter box could bend the thick card slightly and the thin card substantially. The heavier box made the thin card collapse. The forces involved here were the weights and the distortion forces arising from the bending of the various "bridges". Both forces could be varied to produce a range of equilibrium situations. A situation in which the distortion force could not balance the weight was deliberately included to make clear that equilibrium was not inevitable.

Overall, these three were designed to show equilibrium between pairs of forces, which could be regarded as acting in a straight line, in different contexts, involving several different examples of forces, some occurring in more than one of the contexts. It was intended that every child would be interviewed about all three so that consistency of understanding and capacity to generalise across the three examples could be explored.

The interview questions

The questions were developed in conjunction with grids displaying aspects of observation, identification and explanation relating to the three situations. As mentioned above, our approach was to design probes which originated both from the scientific understanding of the phenomena involving forces, and also from the simplest notions children have about these phenomena. For example, for the "Hanging box" we wanted to look for an understanding of the weight of the box as a downward force on the elastic, of the force upwards from the finger, of the forces in both directions from the stretched elastic, and of equilibrium.

	Weight	Hanging box (balanced situation(	Bridges (balanced situation)
Observation of phenomena/cause and effect	The weight can be moved. .. more easily on a smooth surface .. with more difficulty on a rougher surface	The elastic stretches (not breaking). The box is hanging (not falling).	The card bends (does not break/fall off). The box is held up (does not fall through).
Explaining phenomena/cause and effect in terms of properties of objects involved	.. because the rougher surface is harder/has sticky bits	.. because the box is heavy. .. because the elastic is strong .. because the box is not too heavy	.. because the box is heavy .. because the card is strong .. because the box is not too heavy
Explaining phenomena in terms of single push/pull	Pulling makes the weight move. Pushing makes the weight move.	.. because the hand is pulling the elastic .. because the box is pulling the elastic	.. because the box is pushing the card
Explaining phenomena in terms of support		.. because the elastic is holding the box	.. because the card holds the box up

Fig.3 First sample grid showing explanations of test situations

Our approach to this involved identifying what could be simple ways of perceiving and explaining the situation.

We were aware from past studies, notably work on common sense reasoning (Bliss et al., 1989) that children's experience of cause and effect might result in simple notions which appear to be a long way from the scientific understanding. Through item trial we found out more about these simple perceptions and explanations and these enabled us to tease out "basic features" of understanding in relation to the three situations. For example, some children explained the stretching of the elastic in terms of properties of the objects involved, such as "stretchiness" of the elastic, or the "heaviness" of the box. Other children explained the situation in terms of a single push or pull, such as the hand is pulling the elastic, or the box is pulling the elastic. The characterisation of these and other explanations is shown in the first column of the sample grid shown; this sample shows issues explored at the beginning of each interview.

The contents of the cells are answers to questions which relate to the categories in column one. Each row of the grid relates to one kind of question asked. The first row relates to the questions "what do you think will happen?/what do you see happening?". The next three rows relate to the question "why?" which evokes explanation.

The simplest understanding of force is often recognised as a notion of "pushes and pulls". To explore the notion of pushes and pulls, the next part of our probe is to see whether children identify source and direction of pushes and pulls in each situation. Children may identify these unsolicited, if they do not then specific questions are asked. The next few rows of the grid show answers to questions such as "is the box pushing down?", "is the box/your hand pulling up/down?" Following this the grid has questions to do with identifying an external pull (gravity) and relating it to weight. Children are asked "is something pulling the box down?"

The interview is then used to probe ideas of relative sizes of pushes and pulls, and notions of equilibrium. Children are asked about whether situations are balanced, and whether pushes and pulls in opposite directions (if identified previously) are the same or whether one is bigger than the other. This part is shown in the second sample grid.

Thus, this interview schedule uses the three situations to explore children's predictions, observations and explanations of the phenomena in their own terms, and to then probe further the ideas shown on the grid. The interview proceeds according to the answers given by the children. Rather general open questions, sometimes covering several successive row blocks of the grid, are used first, and are followed by more specific and leading questions if natural follow up of the first responses does not cover some of the issues. If the child uses the terms force, gravity, friction, then the interviewer pursues the meanings the child attaches to these terms. If the child does not mention these terms, then after all three items have been used to explore the ideas on the grid, the interviewer probes for the child's understanding of these three and explores how he or she identifies them in each of the three situations.

The grid was developed by an iterative process, starting from the main steps of the science ideas and then modifying by feedback from pilot interviews. The feedback both enriched the detail and led to changes in the ordering, which were always made with the aim of keeping the interview sequence for each of the three situations as equivalent as possible. The outcome is both a useful tool for exploring the domain and a first map of that domain.

Explaining different situations in terms of relative magnitude of pushes/pulls/ distortions	A rougher surface pushes against the weight more than a smoother surface	A heavier box pulls down more. Thicker elastic pulls more for the same stretch	A heavier box pushes down more. Thicker card bends less while giving the same push.
Identifying balance		The situation is balanced when the box is not falling down.	The situation is balanced when the box is not falling down.
Explaining balance in terms of properties of objects		The weight of the box is balanced by the strength of the elastic	The weight of the box is balanced by the strength of the card.
Explaining balance in terms of size and direction of pushes/pulls		The downward pull is equal to the upward pull.	The downward push is equal to the upward push.
Explaining unbalance in terms of size and direction of pushes and pulls	When the push from your hand is bigger than the opposing push the weight moves	When the pull (weight) of the box is greater than the pull of the elasstic, the elastic breaks.	When the push (weight) of the box is greater than the push of the card, the box falls down.

Fig.4 Second sample grid showing explanations of test situations

PRELIMINARY RESULTS

Each interview, involving all three items, takes about 20 minutes and all interviews are tape recorded and transcribed. The following brief extracts from interviews with 7 year olds may indicate some of the issues that are beginning to emerge. The first is from situation (b) in which the student has identified that there is a force on the suspended box going up and that the stones in it are forcing it to go down:

I (interviewer) Is the force going up the same amount as the force going down ?
P (pupil) No, 'cos that's bigger and that's smaller so that'd be going down more and that going down, up, less.

This same student subsequently said that he did not think that the string, when used in place of the elastic, underwent any stretching at all. The second extract is the answer of a student when asked why he had said, for the bent bridge in situation (c), that the system was not balanced :

P. Might be balanced on these sides but not in the middle 'cos it's going down.

Later on, after seeing the bridge collapse with the heaviest weight on the thinnest 'bridge', he thought differently about the forces:

I. So are they the same ?
P. Mmm yeah
I. When aren't they the same ?
P. When that one falls through.

The last example comes from a student who said that the card (bridge) was not pushing up on the weight; when asked whether the two end blocks were doing anything, he said:

P. They're holding the card, supports them (I. they're pushing up are they ?) Well, they're not exactly pushing up but they're keeping this up.

A few moments later this pupil cut across the interviewer's next statement to say :

P. Never heard of it before.
I. Never heard of it before ? Never heard of what before ?
P. This being pushing.
I. This being pushing ?
P. It's holding so it's kind of pushing.

Whilst analysis of responses in terms of the interview grids can reveal whether and how children follow the various steps envisaged, the above extracts show how distinctive features of the pupils' country may also emerge. In this country, the notion of equilibrium is not used: equilibrium situations require no explanation in terms of forces since there is no event to be explained. It may follow that there is no vocabulary to convey the concept, the term 'balanced' being taken to refer to symmetry of shape. It also follows that the primitive notion of support is not linked to experience of forces, and that those supports which show evident distortion - such as thin elastic - are seen as exceptions rather than as examples of a general rule that all supports undergo some distortion. In the detailed analysis of the protocols for the different ages, an attempt will be made to map such responses; it is too early to say whether progression in these can be related to the progression in relationship to the science world criteria.

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REFERENCES

Andersson, B. (1986). The experiential gestalt of causation: a common core to pupils' preconceptions in science. European Journal of Science Education, 8, 155-171.
Bliss, J., Ogborn, J., & Whitelock, D. (1989). Secondary school pupils' commonsense theories of motion. International Journal of Science Education, 11, 261-272.

Carey, S., Evans, R., Honda, M., Jay, E., & Unger, C. (1989). 'An experiment is when you try it and see if it works': a study of grade 7 students' understanding of the construction of scientific knowledge. International Journal of Science Education, 11, 514-529.

Claxton, G. (1991). Educating the inquiring mind: the challenge for school science. London: Harvester Wheatsheaf.

Clement, J., Brown, D.E., & Zietsman, A.(1989). Not all preconceptions are misconceptions: finding 'anchoring conceptions' for grounding instruction on students' intuitions. International Journal of Science Education, 11, 554-565.

Denvir, B., & Brown, M. (1986). Understanding of number concepts in low attaining 7-9 year olds: Part 2. The teaching studies. Educational Studies in Mathematics, 17, 143-164.

DES [Department of Education and Science] (1988). National Curriculum Task Group on Assessment and Testing: A report. London: Department of Education and Science and the Welsh Office.

Di Sessa, A.A. (1983). Phenomenology and the evolution of intuition. In D. Gentner, & A. L. Stevens, (eds.) Mental models. Hillsdale, New Jersey: Lawrence Erlbaum.

Driver, R. (1989). Students' conceptions and the learning of science. International Journal of Science Education, 11, 481-490.

Gunstone, R. F., & White, R. (1980). A matter of gravity. Research in Science Education, 10, 35-44.

Hayes, P. J. (1979). The naive physics manifesto. In D. Mitchie, (ed.) Expert systems in the microelectronic age. Edinburgh: Edinburgh University Press

Osborne, R., & Gilbert, J.K. (1980). A technique for exploring students' views of the world. Physics Education, 15, 376-379.

Pfundt, H., & Duit, R. (1991). Bibliography: Students' alternative frameworks and science education (3rd edn) Kiel: IPN - Institute for Science Education.

Scott, P.H., Asoko, H.M. & Driver, R. (1992). Teaching for conceptual change: a review of strategies. in Duit, R. et al.(eds.) Research in physics learning: Theoretical issues and empirical studies. Kiel: IPN - Institute for Science Education.

Solomon, J. (1983). Learning about energy: how pupils think in two domains. European Journal of Science Education, 5, 49-59.

White, R.T., & Gunstone, R.F. (1989). Metalearning and conceptual change. International Journal of Science Education, 11, 577-586.

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STUDENTS' PERCEPTIONS OF AN INNOVATIVE UNIVERSITY LABORATORY PROGRAM

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ABSTRACT

This paper presents some of the findings of a naturalistic study of a first year university biology laboratory. We report on the affective outcomes for a field trip and a practical exercise that incorporated innovations aimed at increasing the scientific realism and students' responsibility in the learning process. Concern with assessment procedures and a perceived lack of teaching support dominated outcomes for students. Feelings of confusion, lack of satisfaction and hostility were evoked. Recognition of the need to foster greater student input into the learning process is commended, but this paper raises issues about the strategies utilised.

INTRODUCTION

This paper presents some of the findings of a naturalistic study of first year biology university students. It focusses on a field trip and a practical exercise on enzyme properties that were the first sessions in the year.

In earlier studies in this area, Adamson (1976) found that some lecturers did not organise field trips for first year biology students because of large enrolments and heavy marking loads, while other lecturers did so, despite large enrolments. Raghubir (1979) criticised prescriptive laboratory tasks for not providing the opportunity to experience the processes through which scientific information is generated: hypothesis formulation, experimental design, analysis and interpretation of results. Further, "teachers tell students too much to save time, and to save the experiment" . Raghubir also argued that labwork should foster attitudes such as curiosity, openness, responsibility and satisfaction. Dunkin and Barnes (1986, p.766), in their review of teaching in higher education, suggested there is a barrier to recognising the importance of attitude in the learning process. "It is as though the classrooms of higher education are not only inappropriate contexts in which to display such things as emotions, but that they are also in-appropriate places in which to conduct research on emotions". Bliss and Ogborn (1977) have identified that a feeling of independence is a significant part of good stories on laboratory work from tertiary students.

THE PRESENT STUDY

In the present study, conducted with first year university biology students there was a clear intention to promote student enterprise. The subject was redesigned with the aim of increasing the scientific realism of practical exercises and to avoid "spoon-feeding" students. Repetitive dissections and prescriptive experiments were replaced or adapted to include assessed discussions, student designed experiments, presentations and the collection of original data. Two strategies adopted to increase student independence were regular changing of the demonstrator and minimal demonstrator input at particular times. The subject includes two field trips requiring written reports. A major objective of one of these was to provide students with an opportunity to collect original data and write a report in a journal format, thereby simulating in part what scientists do. In the laboratory task on enzymes, students had to design and carry out an experiment as a group, and the demonstrators were instructed not to have input into the experimental design in an effort to enhance student independence. The environment and time structure of the practical program were typical of those described by Adamson (1976). There was one 3-hour session per week; groups of 15-16 students were allocated a demonstrator, drawn mainly from the graduate student population and in the year of this study, rotated every three weeks.

METHOD

Participants

The experiences of two groups of students from March - October 1991 were examined in detail. Most students had come directly from secondary colleges, as was the case for the 600 students enrolled in the course. All group members agreed to participate in the study. Both groups originally contained 15 students each. There were some drop-outs; 27 students were interviewed initially and 24 for Interview 2 (12 each group).

Interviews

This paper draws on two semi-structured one-to-one interviews of one hour duration. Interview 1 was a familiarisation interview and aimed at building a profile of student beliefs about learning and general impressions of the course to date. For convenience, interview questions on the two practicals are placed appropriately in the text. As both practicals provoked strong emotional responses, it made sense to return to them in a second interview four months later to gain a sense of the strength of the episodes.

Observations

Four of the eight field trips and the enzyme practical of Group 2 were attended by the first author as a participant observer. Students' questions to staff, their interactions with each other, in particular how they carried out the tasks as a group were noted. Students were also asked about their understanding of what they were doing.

FIELD TRIP

Assessment

The report contributed a possible 3% to the semester score. The mean score was low (40% ± 14), and anticipated. The following instruction was given to students. "Your mark should be treated realistically; indeed, the lower the mark the more positive you should feel about the changes you will make in the next project."

Observations

Demonstrators were not used, partly to reduce costs, and partly to place greater responsibility on students. The student-staff ratio averaged 26:1. Preparation included a lecture, a written description of tasks in the manual and a ten minute introduction.

In groups, students quantified and estimated the ages of the *Eucalypt* species in a sample 100m^2 quadrat. The results were scaled up to allow density comparisons between differing sites and this formed the basis of the report. Generally two to four students per group carried out this task. Twenty minutes was allocated and the staff assisted by moving between groups. Students were rushed to complete the study accurately. The groups then constructed ten ecological questions and a high level of enthusiasm ensued. A lecturer judged a class discussion where each group had to design an experiment that might solve one of these questions. The class size was between 60-90 students, and input was from the minority of students.

Student Experiences (Interview 1)

Q1. *Tell me about your experience of the field trip.*
Comments on the field trip also arose in response to:
Q2. *What has been your worst/best practical to date? Why?*

Half the students reacted favourably to the field trip. They commented that it was good to get out and some noted surprise at their interest, although all these students qualified their comments with concern about lack of clarity and staff support. Other students said it was a joke or boring. Students differed in their evaluation of the large discussion; it was overwhelming for some, while others enjoyed and recognised the importance of devising questions and thinking about how to solve them. In contrast, students overwhelmingly indicated the field trip was tarnished by the low report marks.

Example 1: "Good except that before we went it should have been better explained what we were doing, if they had more demonstrators, I know they are trying to cut costs, but you really needed a demonstrator, there was no direction, ... it was a lot of confusion."

Example 2: "I didn't like the field trip at all. ... We got down there and got told that was your area, and there was two people out of the group who knew what was going on and we just stood around and copied whatever they wrote."

Example 3: "It was good to go out and look at the variety and compare different sites. When I got my report back I thought I'm never going on a field trip again."

Thirteen students said it was their worst practical; this could be attributed to a sense of disgrace from a low score. Eight students immediately began talking about the report at the start of the interview stating they were "angry", "scared", "worried", and "confused". Others said the exercise was "pointless" or "unfair". Their sense of injustice was associated with hours writing the report, the majority reporting 4-6 hours.

Example 4: "The write up was a useless waste of time. I don't think it achieved anything. I got 11%, it's nothing that I have ever had to cope with ... I don't know if it was meant to serve to humiliate us."

Example 5: "I hated it, if that is what I'm going to get after 4 hours of writing a report they can forget it. So when you get to University you fail good!"

Example 6: "I know we're meant to be thinking for ourselves but ... more background on what they were really after, ... I didn't mean them to spell it out. There was a lot of information on how to write your introduction and methods but [they] didn't say what the actual discussion was about.

Student Reflections (Interview 2)

Q1. *What did you learn about the study of biology from the field trip?*
Q2. *Would you feel more or less confident if asked to write a similar report?*
Q3. *How did you feel when you got your mark back?*

Students could only provide minimal conceptual details for Question 1 and often chose to discuss the report, saying they now realised a strict format had to be followed while others said they learnt they could not write a report. If asked to write a similar report, fourteen students stated they would be less confident, nine said more or probably more confident and one much more confident. Students recalled clearly their sense of injustice.

Example 7: "I realised I needed a broader understanding of plant communities, which I don't, and still don't. I learnt there is species specificity on slopes."

Example 8: "Reinforced my feelings about group field trips with teenagers, they're disasters. I don't know why people keep sitting group work with teenagers, I've never been in a group where we've actually got something done."

Example 9: "[I remember] that it was totally unfair and no actually, let me think of something more rational, I wasn't surprised, not because I didn't put the work in but because it was a forgone conclusion everyone was to fail. They said don't worry everyone gets 36, it was totally negative from the start. ... It was not encouraging at all. ... I will always be bitter about that."

Example 10: "For our first [marked] prac, it destroyed a lot of people. ... Perhaps they should have marked easier, pointed out the problems and then marked the next one harder. This one was such a dampener, a lot of people put in a lot of work. ... it got a huge reaction."

Example 11: "Every time people talk about it they say nothing made sense and they marked hard. No one cares about trees that much I don't think. I did go into it with an open mind, botany has never been a favourite of mine but I was willing to give it a chance, it really didn't do much. ... human biology, that really gets you ... with plants, I don't know how they feel."

ENZYME PRACTICAL

Assessment
The experimental design represented 7% of the semester mark and demonstrators were instructed to assess by the following criteria: one tick if students said something, two ticks when their contribution was very helpful and three ticks if they contributed in an outstanding way to the discussion.

Observations

A demonstrator change coincided with this practical. This frequent changing was motivated partly to avoid groups having an inexperienced demonstrator for an extended period. It was also part of the strategy to enhance student independence, and to avoid the potential for favouritism during the assessment.

The first question to the new demonstrator for Group 2 was, "Why have we changed demonstrators?" The demonstrator responded with, "I don't know" and quickly focused them on the practical. This interaction was very significant as it meant initial rapport was not developed. The demonstrator introduced the various prescriptive experiments that preceded the experimental design and followed them up by asking students for their results. When results did not fit the expected outcome the demonstrator asked for another result. Once the 'correct result' was heard he then explained why it occurred. The demonstrator tried to maintain a fast pace, aware that there was a lot to do. When the group attempted to discuss any unusual findings, they were thwarted by the demonstrator.

The subsequent group discussion on experimental design became disjointed very quickly, as many students spoke at once and no coherent structure was developed. Four students dominated and five students said nothing or made one comment while the demonstrator remained silent as he assessed proceedings as instructed. The group could not agree on a design and divided, attempting to carry out different experiments in the last 20 minutes available.

The comment on the mark sheet said the group was disorganised. During the laboratory task the demonstrator intimated that this was a dumb group, and although there were a couple of good students, they were held back by the others. The Group 1 demonstrator stated that he chose not to follow the instructions of no facilitation as the group discussion was confused and the concept of a control was not understood.

Student Experiences (Interview 1)

Q1. *How did you feel about the demonstrator changing?*
Q2. *What has been your best/worst practical and why?*

As observed, the lack of rapport with the new demonstrator had made a large impact on Group 2. However this was not always the main focus of their concern, as the interview went on to explore their experience in more detail. There was concern with the lack of boundaries, the poor group interaction and the assessment procedure. The major concern of Group 1 was the lack of structure in the experimental design. In all, seven students stated it was their worst practical and two stated it was their best because it was real science and they had prepared well.

Example 12: "We got on really well with our other demonstrator, we were all interested, and he was interested too, whereas our demonstrator yesterday didn't relate at all too us, ... which really rubbed everyone up the wrong way. Bill would have guided the discussion a bit ... I suppose he was meant to be marking how we were relating but I guess it was just because everyone was a bit peeved we swapped demonstrators."

Example 13: "... (there was a) lack of unity, it got to the point where we were saying you do it your way and we'll do it our way. ... We lost sight of what we were trying to do ... Jean was writing it down to get it structured, it really needed to be done, ... go through one stage at a time and discuss it, we never established the basic structure and funnily enough it didn't work. [laugh]" [Jean did not say anything during the discussion and so received no individual score.]

Example 14: "There was so many people yelling and getting really stressed, I was really peeved by the end of that prac yesterday."

Example 15: "Last week we were given the exercise of designing our own experiment. That makes you really dig into your resources ... I sat down the night before and came up with some great idea ... that's when I'm learning the best rather than the demonstrator up at the board saying this and this. ... that's really what science is all about."

Students' Reflections (Interview 2 - Group 2)

Understanding of concepts explored in the practical and subsequently assessed in an exam were investigated but is not reported here. Group 2 students readily recalled the lack of rapport with their demonstrator, but directly linked this issue now with their learning. They had reflected more on the assessment procedure and were highly critical, as many perceived the process to be intimidating and disadvantaged students who could not or chose not to compete with the more dominate and articulate speakers.

Example 16: "I didn't like [the demonstrator] ... he refused to answer our questions, he said "you really should be doing this yourself" ... I don't think it is good to have a challenging demonstrator, there is enough in the material without having to tackle your demonstrator to get information."

Example 17: "He was completely cold and he didn't really care at all ... that was when the group sort of disintegrated, no one particularly liked him, he was very dry, he knew what he was talking about so you could ask him a question and get a decent answer. ... he created a barrier, it was very hard for people to understand, we weren't willing to listen, type of conflict really, wasn't much group participation."

CONCLUSION

The majority of bad stories cited by undergraduate students concerning laboratories involve negative interpersonal feelings: self doubt, inability to get adequate guidance from the teacher and annoyance at the situation (Bliss, 1990, p. 388). These practicals aimed to provide a stimulating learning context, yet these bad feelings dominated. Other factors that contribute to negative attitudes towards labwork, insufficient time and excessive challenge (Gardner & Gauld, 1990), were also present. For the field trip though, it was the impact of low marks that had a devastating effect on the self esteem of students. For such a small contribution to their overall assessment, it was a momentous and dubious episode.

In the enzyme practical the lack of rapport with the new demonstrator was clearly a major reason for the negative attitudes displayed by Group 2, but the combination of circumstances —a busy practical, the assessment responsibility, and the instructions not to facilitate the experimental design —also contributed. The demonstrator's belief that these students were dumb, also raises an issue on the lack of support and training of demonstrators. It is important to note that this demonstrator was experienced and well acquainted with the content.

No facilitation of the group design meant there was no option to draw less confident students out. Simply allowing students to interact does not mean that high-quality peer relationships will develop and that learning will be maximised (Johnson & Johnson, 1991). While removing teachers at times can enhance student independence, changing them as well disrupted the relationship and so the learning. While the decision by the Group 1 demonstrator to facilitate cannot be criticised, the issue of equity in the assessment procedure is brought into question.

Until relatively recently this laboratory program had the hallmarks of traditional biology practicals as described by Adamson (1976). Here, the major changes were primarily motivated by educational concerns and only secondarily by budgetary constraints. Reduced budgets, together with the increasing recognition that laboratories often fail to promote the learning intended (Hegarty-Hazel, 1990, p. 3), make competing demands when decisions are made to initiate change. Although the recognition of the need to foster greater student input into the learning process is commended, this paper raises issues about the lack of awareness of the different role demonstrators might play within that framework, but perhaps more critically, the lack of awareness of the vulnerability of students. Richard Livingstone said "The heart is a more reliable organ than the brain" (cited in Smith, 1990, p. 200) and this epitomises the need to watch closely innovations in higher education.

REFERENCES

Adamson, H. (1976). Undergraduate education in the biological sciences in Australian universities. Unpublished Ph.D. thesis, Macquarie University.

Bliss, J. (1990). Students' reactions to undergraduate science: Laboratory and project work. In E. Hegarty-Hazel (ed) The student laboratory and the science curriculum London & New York: Routledge.

Bliss, J., & Ogborn, J. (1977). Students' reactions to undergraduate science: Laboratory and project work. London: Heinemann Educational Books.

Dunkin, M.J., with the assistance of Barnes, J. (1986). Research on teaching in higher education. In M.C. Wittrock (ed) Handbook on research on teaching (3rd edn) New York & London: Collier McMillan.

Gardner, P., & Gauld, C. (1990). Labwork and student attitudes. In E. Hegarty-Hazel (ed) The student laboratory and the science curriculum London & New York: Routledge.

Hegarty-Hazel, E. (1990). The student laboratory and the science curriculum: an overview. In E. Hegarty-Hazel (ed) The student laboratory and the science curriculum London & New York: Routledge.

Johnson, D.W., & Johnson, R.T. (1991). Learning together and alone. Cooperative, competitive, and individualistic learning (3rd edn) Boston: Allyn & Bacon.

Raghubir, K.P. (1979). The laboratory-investigative approach to science instruction. Journal of Research in Science Teaching, 16 (1), 13-17.

Smith, P. (1990). Killing the spirit: Higher education in America New York: Viking Penguin.

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AN ECOLOGICAL PERSPECTIVE ON RESEARCH WITH COMPUTERS IN SCIENCE EDUCATION

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ABSTRACT

This paper presents an "ecological perspective" on research with computers in science education. It is proposed that current and past research within the computer education field has been characterised by an over-emphasis on technical applications of the machinery, rather than a deeper consideration of the teaching and learning process. This tendency toward "technocentric thinking" has usually failed to take into account the important social and cognitive interactions within the computer learning environment. The view advanced here, is that an understanding of the effects of computers on students' learning can be achieved only through an analysis of the dynamic interactions between students and teachers as they work with computers in a particular environment. A theoretical framework for understanding this range of interactions is presented. Finally, an ecological model is proposed for conducting future research on the application of computers in science education.

INTRODUCTION

Computers have become increasingly common in New Zealand schools. A recent research report coordinated by the International Association for the Evaluation of Educational Achievement (IEA) shows that most students have access to computers and that they are now used in all parts of the curriculum (Nightingale & Chamberlain, 1991). While the applications of computers and associated products of technology are still in their infancy in science education, it is evident that computers will have an increasing role in the science curriculum. The recent 'National Curriculum of New Zealand — Discussion Document' stipulated that access to information and communication technologies (however these are defined) will be essential "to improve the efficiency of learning" (Ministry of Education, 1991, p.13). Indeed, this view has enthusiastic support. The Minister of Education recently stated "high levels of technological literacy are vital if this country is to respond successfully to the challenges of the modern, international, competitive environment" (Smith, 1992, p.4). However, amid growing enthusiasm and official support for the wider application of computers and related outcomes of technology, there remains a potentially dangerous assumption. It appears to have been largely assumed that the use of advanced computer 'technologies' will automatically enhance student learning. As learning difficulties cannot be cured through any technological fix, there is a need for research to understand the role of computers in teaching and learning.

This paper examines the applications of computers and associated 'technologies' as they relate to science education. It outlines some of the problems associated with previous research on the use of computers in education and advocates an ecological perspective for analysing their effects on learning. An ecological perspective promotes an analysis of the inter-related systems and dynamic interactions among all the elements in a computer learning environment. This environment is discussed in relation to the classroom and the culture that develops from the interactions among teachers, students, computers, curricula and outside social systems. An integrated social-cognitive theoretical framework is outlined for analysing this culture and an ecological model is proposed for conducting research on the multi-systemic interactions that establish a particular learning culture. Finally, a number of recommendations are suggested for future research on computer applications in science education.

PREVIOUS RESEARCH

A great deal of research has been completed on the use of computers in education. Most of it is characterised by an over- emphasis on technical aspects of the machinery (Ryba, 1991): the focus has been largely upon the features inherent within the technology, specific hardware devices and software applications. This focus has led to numerous attempts to measure the machine effects on learning. The literature has been dominated by 'technocentric' studies that try to consider the effect of the computer *per se*. These studies have reflected a reductionist and largely experimental paradigm. Their objective has been to determine whether the computer is more effective than traditional methods of instruction.

This type of research usually focuses on a particular computer application and seldom considers an existing educational problem. The application is often studied for only a limited period, is generally isolated from the curriculum, and controlled through a treatment and non-treatment experiment. The aim has typically been to isolate the effects of the computer on learning by attempting to control all the intervening variables.

The problem with such a research design is that it largely misses the point. It is not the machine *per se* that directly influences learning but the way that people use it and interact with one another. As Ryba and Anderson (1990) maintain, it is the people effects, not the machine effects that are important for learning. By overlooking the important people effects many significant social and cognitive outcomes have been ignored. Previous research has tended to disregard contextual variables such as student interaction and learning styles, affective and motivational domains, curriculum requirements, social and cultural influences, and the role of the teacher/researcher. Indeed, the teacher's view of the learning process, pedagogical approach, and expectations for learning have rarely been researched or controlled.

In sum, previous research on the use of computers in education has not been guided by an explicit theory. The research has focused on the computer and neglected a deeper consideration of the teaching and learning process. It has failed to take into account that the computer is but one element of a learning environment. All the elements within a learning environment have an important effect upon students' learning. As Salomon (1990) points out through the analogy of a symphony orchestra - "the music we enjoy is produced by symphonic orchestras, not just single flutes" (p.530). In advocating a more holistic approach to research Papert (1987) has suggested that learning occurs from the culture that develops as a result of the dynamic interactions within a particular environment. It is from an understanding of the relationships and interactions that create this culture, that research will be able to suggest the ecological effects that computers and related 'technologies' have on learning.

AN ECOLOGICAL PERSPECTIVE

The adoption of an ecological perspective is not new in education (see Bronfenbrenner, 1977). While this familiar scientific term has been interpreted in a number of ways, it is used in this paper to suggest the study of inter-related systems and connections between elements within a particular learning environment. The strength of studying the learning environment in this ecological way is that the various elements and systems must always be considered in relation to each other. No one element or system is seen in isolation. There are multi-systemic components to the learning environment that interact to create what has been called a *computer learning culture* (Papert, 1980). The following diagram suggests the ecological composition of the computer learning environment. It indicates the nature of the relationships and interactions between the various systems that combine to form a computer learning culture (Fig. 1).

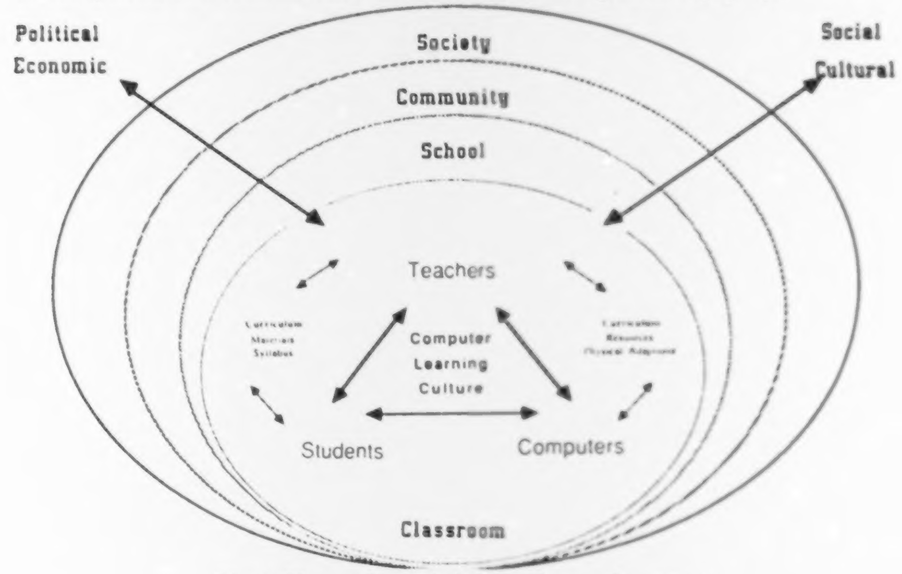

Fig. 1 The ecology of the learning environment

This schematic representation of the learning environment shows how teachers, students, and computers are in constant interaction. It demonstrates that these interactions occur within and across a definite micro, mesa, and macro system context. There are important political, economic, social, and cultural influences at and between the society, community, school, and classroom level. The learning culture that develops from the activities between these levels and inter-connected systems consists of the shared meanings, beliefs, symbols, materials, and experiences through which students make sense and learn. The arrangements and inter-related elements that create a particular learning culture are usually difficult to define. They are by nature dynamic and unique to each learning environment. The complex interactions within a learning environment mean that a clear theoretical framework is required to analyse the relationships that combine to create a specific learning culture.

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In sum, an ecological perspective focuses upon the interactions between the systems within a learning environment, not upon the computer per se. As Papert (1987) has pointed out, "the computer is but one element of an educational culture. The context for human development is always culture —never an isolated technology" (p.23). While the products of technology have an important role, it is the dynamic interactions between computers, students, teachers, curricula, and wider social systems that is central to what is learnt. The effects of computers on learning can only be understood from a sound theoretical analysis of the interactions between all the inter-related systems within the ecology of the learning environment.

A THEORETICAL FRAMEWORK

With this ecological approach in mind the following section outlines a theoretical framework for analysing the interactions between the various elements and systems that combine to create a computer learning culture. An integrated social-cognitive theoretical framework is proposed as a useful construct for understanding the development of a computer culture and the conditions for learning in science. There are three main aspects to this theoretical construct: a triarchic theory of information processing; a constructivist perspective on learning; and a social-dialogical account of culture. The significance of these theories is that they are considered complementary, rather than mutually exclusive.

TRIARCHIC THEORY

The triarchic theory of human information processing is a process-oriented model of cognition (Sternberg, 1985). As an adaptive process, cognition is considered as having three integrated dimensions: componential; contextual; and experiential. The componential dimension relates to the internal mechanisms that underlie intelligent behaviour. The contextual component accounts for the external world of students and the mechanisms they adopt to attain a fit to their environment. The experiential realm explains cognitive activity with regard to an individual's cumulating and shared experience. While each of these sub-theories is useful in understanding the interactions that are important for learning, the componential dimension is particularly relevant. In the componential sub-theory there are three basic components: metacomponents; performance components; and knowledge-acquisition components. While knowledge-acquisition components are the processes used in learning new information, and performance components are the processes used in executing a task, metacomponents are higher order control processes that are used for executive decision-making (Sternberg & Frensch, 1990).

These higher order executive skills are closely related to Flavell's (1976) original concept of metacognition. Metacognition is generally defined as the cognitive processes that occur when students become aware of their own thinking activities and consider ways that these can be regulated (Brown, 1978). These higher order regulative self-management skills are thought to underlie the effective use of learning strategies (Ryba & Anderson, 1990). While the term *learning strategy* has become somewhat nebulous, these are usually defined as either general heuristics or specific tactics organised and planned to achieve a goal. The significance of these learning strategies and metacognitive skills is that they are considered as attributes of the ability to learn how to learn. The importance of learning how to learn implies that research on computer use in science education ought to focus on the type of arrangements and interactions that facilitate such learning.

CONSTRUCTIVIST THEORY

The constructivist perspective of learning has a relatively long tradition. However, its recent history in science education originates from Kelly's (1955) theory of personal construct and Ausubel's (1963) notion of meaningful learning. (For more recent contributions, see Driver, 1983.) The basic tenet of constructivism is that learning is an active process of making sense of experiences in terms of prior knowledge (Osborne & Freyberg, 1985). This constructivist view of knowledge and 'making sense' is currently the dominant theoretical orientation in science education.

In the field of computers in education constructivism has had a slightly different origin. Constructivist theory has originated mainly from Piagetian and social learning theory. This blend is based upon a view that while learners are active in constructing their own cognitive structures, these are learnt in a social and cultural context, which is believed to influence directly what and how a student learns.

The social dimensions embodied in this version of constructivism have only of late begun to gain prominence in science education. The social nature of learning in science has been illustrated recently by Tobin (1990) who argues that people belong to a culture which uses language and this is itself a product of social construction. This social constructivist view is founded upon the notion that language and meanings have their root within culture. To quote Tobin, "the meanings of words and symbols have within them a component of culture that can never be removed, and without which, theory would not be possible" (1990, p.31). This means that a student's meanings and understandings of the world are determined as much by a group's shared and collective experience as they are by the knowledge and cognitive processes of the individual.

The convergence between these different constructivist perspectives means that social interaction must be regarded as an essential element in the negotiation and individual construction of knowledge. This view of knowledge highlights the point that research on computer use in science education ought to focus on the relationships between systems that directly impact upon language and social exchange.

SOCIAL-DIALOGICAL THEORY

A social-dialogical account of learning and culture complements these triarchic and constructivist perspectives. There are three underlying themes that unify Vygotsky's (1978) social-dialogical view of learning: the importance of culture, the central role of language, and the zone of proximal development.

In discussing the significance of culture Vygotsky claimed that a student's experiences were initially encountered on an inter-psychological plane i.e. within the social and cultural mores of a particular group. These experiences were only understood at the intra-psychological or cognitive plane when they had been socially mediated from a student's culture (Wertsch, 1985). This mediation was believed to occur via purposeful and patterned activity within the shared perceptual space from which people mutually construct their meanings. Roschelle (1992) explains this in terms of situated cognitions within a community of practice. *Community of practice* is used here to mean a social unit that shares a stake in a common situation. While this is a complex theory the important thread is that culture is believed to be the context within which learning occurs.

In outlining the central role of language Vygotsky (1978) distinguished between elementary and higher order mental functions. The movement from elementary toward higher mental processes was attributed to cognitive tools and the mediation of sociocultural signs (symbol systems such as language). Vygotsky categorized language in terms of three specific types: *social speech*, such as that used by toddlers, *egocentric* speech, as used by young children talking to themselves, and *inner speech*, the silent self-talk that enables people to direct their thinking and behaviour. Vygotsky theorized that inner speech was the developmental binding of language and thought. A key feature of this theory was that speech and action were thought to be directly related (Wertsch, 1985). It was maintained that students use speech and action together in the development of higher mental functions and in the process of problem solving.

The connection between problem solving and metacognitive type processes is significant. Vygotsky (1978) maintained that awareness and control of one's own thought processes was based in social interactions with other learners. Through communication and cooperation with more capable peers students learn how to progressively understand their own cognitive processes and control their own learning. However, Vygotsky emphasised that the self-regulation of thinking or metacognitive activities, were directly connected to the zone of proximal development (Moll, 1990). The zone of proximal development referred to the distance between actual development, as determined by independent problem solving and the level of potential development, as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978). It was from scaffolded student-student and student-teacher interactions within this zone that higher metacognitive type functions were claimed to occur.

In sum, this integrated theoretical construct derived from a triarchic theory of information processing, constructivist perspective of learning, and social-dialogical account of culture recognises the mutual importance of both social and cognitive aspects of learning. The construct is based upon a view that cognition is an inherently social phenomenon. It argues that the social organisation of an environment cannot be separated from the analysis of thinking and learning. Indeed, as Ryba and Anderson (1990) maintain, social development in the computer environment is an essential vehicle for cognitive growth. These integrated perspectives demonstrate that there is a crucial link between the acquisition of cognitive self-management skills and social development. In emphasizing the social and shared aspects of cognition the theoretical framework highlights the need for research focussing on the social-cognitive and ecological interactions through which learning and culture develop.

AN ECOLOGICAL RESEARCH MODEL

The advancement of a social-cognitive theory within an ecological framework suggests a movement from experimental to naturalistic research. This movement reflects the need to understand the multi-systemic nature of the computer learning environment and the range of social and cognitive interactions that are important for learning. The need to study these interactions within the natural setting of the learning environment also requires more than the use of analytical approaches: such methods on their own are normally too insensitive for studying the dynamic interactions between the systems and variables within the learning environment. Instead, research on the use of computers and related outcomes of technology in science education needs to be conducted within a paradigm which adopts a systemic approach: one which recognizes that people and culture coexist, and jointly define one another in contributing to what and how something is learnt (Salomon, 1990).

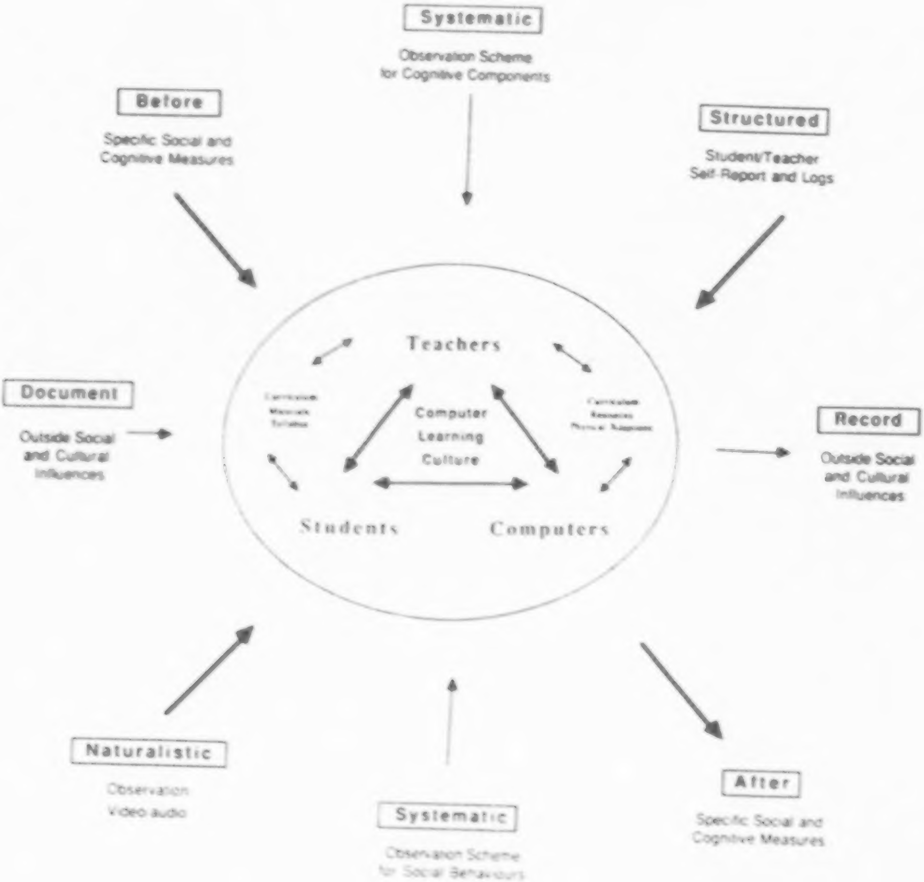
Systematic
Observation Scheme for Cognitive Components
Before
Specific Social and Cognitive Measures
Structured
Student/Teacher Self-Report and Logs
Document
Outside Social and Cultural Influences
Teachers
Curriculum Materials Syllabus
Computer Learning Culture
Curriculum Resources Physical Support
Students
Computers
Record
Outside Social and Cultural Influences
Naturalistic
Observation Video audio
Systematic
Observation Scheme for Social Behaviours
After
Specific Social and Cognitive Measures

Fig. 2 An ecological model for analysing social-cognitive interactions in the computer environment

Although a paradigm is not a research method, it seems that understanding the dynamic interactions between systems within a computer learning environment requires a combination of different quantitative and qualitative techniques (Levine, 1990). The following model presents an ecological approach toward analysing the important social and cognitive interactions that impact upon the growth of a computer learning culture (Fig. 2).

In this model there are four main components to research. The first component refers to traditional experimental procedures used to examine before and after change. The second component refers to systematic observations that are conducted in a variety of ways. The third component focuses upon the analysis of precise teacher and student interactions within a naturalistic computer environment. The final component documents and analyses the influence of wider mesa and macro systems on the development of a learning culture.

The nature of the intra and inter-relationships in this model indicate that there is more to this ecological approach than just a methodology. The adoption of such a model for the analysis of social and cognitive interaction effects requires some quite different research questions. For instance: How do computers and related technologies impact upon the social organisation of learning in science? What arrangement of computers in science education supports social interaction and reflective thinking? How do computers mediate student learning and provide contexts for the development of more useful scientific concepts?In a practical sense this type of research is ideally suited for ethnographic case studies. These allow for holistic analyses of the patterns and intricate web of interactions that combine to a create computer learning culture. Exploratory ethnographic studies are particularly suitable during initial research: they allow for a wide range of social and cognitive interaction effects to be observed and help to define the focus of problems and questions for subsequent research.

CONCLUSION

Computers have had a rapid and fairly ad hoc introduction to New Zealand education (Chamberlain & Kennedy, 1991). It seems certain, however, that computers and associated products of technology will have an increasing role in science education. For this reason, it is important that they are used in accordance with established principles of teaching and learning. Experimental research has been largely unsuccessful in uncovering the factors that explain the conditions under which computer-using students learn; perhaps a multi-systemic research approach may be more fruitful. In the shift to a multi-systemic or ecological paradigm, sound theoretical frameworks are required for analysising the interactions and relationships that create a computer learning culture. While research on the development of learning cultures does not preclude a range of theoretical frameworks, an integrated social-cognitive construct is particularly useful. This construct provides a means for interpreting the important social and cognitive interactions within a particular learning environment. A clear theoretical analysis of these interactions and relationships may help researchers to better understand the ecological effects of computers on learning. A better understanding of these ecological effects will ultimately help educators make wise decisions about the role of computers in science education.

REFERENCES

Ausubel, D. (1963). The psychology of meaningful verbal learning: an introduction to school learning. New York: Holt, Rinehart & Winston.

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. American Psychologist, 32, 513-531.

Brown, A. L. (1978). Knowing when, where and how to remember: problem of metacognition. In R. Glaser (ed). Advances in instructional psychology. Hillsdale, NJ: Erlbaum.

Chamberlain, M., & Kennedy, S. (1991). A case of growing like topsy. Wellington: Research and Statistics Division, Ministry of Education.

Driver, R. (1983). The pupil as scientist? Milton Keynes: Open University Press.

Flavell, J. H. (1976). Metacognition aspects of problem solving. In L. B. Resnick (ed.), The nature of intelligence. Hillsdale: Erlbaum.

Kelly, G. A. (1955). The psychology of personal constructs. New York: W. W. Norton.

Levine, H. (1990). Models of qualitative data use in the assessment of classroom-based microcomputer education programs. Journal of Educational Computing Research, 6, 461-477.

Ministry of Education, (1991). The National Curriculum of New Zealand — A Discussion Document. Wellington: Learning Media.

Moll, L. C. (1990). Vygotsky and education. Cambridge, NY: Cambridge University Press.

Nightingale, D., & Chamberlain, M. (1991). A study of computers in New Zealand schools. Wellington: Research and Statistics Division, Ministry of Education.

Osborne, R. J., & Freyberg, P. (1985). Learning in science: the implications of childrens' science. Auckland: Heinemann.

Papert, S. (1980). Mindstorms: children, computers, and powerful ideas. Brighton: Harvester.

Papert, S. (1987). Computer criticism vs. technocentric thinking. Educational Researcher, 16(1), 22-30.

Roschelle, J. (1992). What should collaborative technology be? A perspective from Dewey and situated learning. SIGCUE Outlook, 21(3), 39-42.

Ryba, K. (1991). What we've got —is it right? Computers in New Zealand schools, 3(3), 12-16.

Ryba, K., & Anderson, B. (1990). Learning with computers: effective teaching strategies. Eugene OR: International Society for Technology in Education.

Salomon, G. (1990). Studying the flute and the orchestra: controlled vs. classroom research on computers. International Journal of Educational Research, 14, 521-531.

Smith, L. (1992). Information and communication technology. Paper presented at the Ministry of Education Information and Communication Technology meeting, Wellington.

Sternberg, R. J. (1985). Beyond IQ: a triarchic theory of human intelligence. New York, NY: Cambridge University Press.

Sternberg, R. J. & Frensch, P. A. (1990). Intelligence and cognition. In M. Eysenck (ed). Cognitive psychology: an informational review. Missouri: John Wiley & Sons.

Tobin, K. (1990). Social constructivist perspectives on the reform of science education. The Australian Science Teachers Journal, 36(4), 29-35.

Vygotsky, L. S. (1978). Mind in society. Cambridge, MA: Harvard University Press.

Wertsch, J. V. (1985). Culture, communication, and cognition. New York: Cambridge University Press.

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STUDENT PERCEPTIONS OF TECHNOLOGY AND IMPLICATIONS FOR AN EMPOWERING CURRICULUM

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ABSTRACT

Growing interest in technology education in 1988 led the Curriculum Development Division of the then New Zealand Department of Education to seek a survey of students' perceptions of technology using the internationally trialled Pupils' Attitudes Towards Technology (PATT) questionnaire. Early in 1989 a national sample of 1,469 form 3 students completed the questionnaire and responded to an open question about the nature of technology. Results indicated that students have generally positive attitudes towards technology, but poor concepts of technology. The nature of these attitudes and concepts and related factors have implications for the development of the National Curriculum Statement in Technology.

INTRODUCTION

Technology has in recent years appeared as an identifiable component of New Zealand school curricula. For example, in 1980, Workshop Technology was included (Department of Education, 1981) as an integration and development of the craft subjects, Woodwork and Metalwork, and other subjects, including Graphics and Design, as a development from Technical Drawing, have followed. The 1980s also saw some science teachers introduced to the Science, Technology and Society movement (Green, 1984) and to learning in science through the study of technological products (Longbottom, 1984; Cosgrove, Newman & Forret, 1987). The numbers of students and teachers involved in these initiatives, however, remained small and the Curriculum Review of 1985-6 (Department of Education, 1987) reflected little community interest in technology education (only two of the 99 recommendations specifically mentioned science or technology). All this was to change in 1986 when the government, concerned about "serious difficulties with traditional export products and ... an urgent need for innovations", set up the Ministerial Working Party on Science and Technology to "review the role of government in science and technology with particular regard to broader government policy and the place of science and technology in the economic and social development of New Zealand" (Beattie, 1986, p. iii). The Beattie Report recommended investment in science and technology, including science and technology education. While proposing more school mathematics and physical science education which would prepare students for technology-based tertiary study (see Walsh, 1987), it reported criticism of the education system in its ability to provide "creativity in the areas of science and technology" and questioned "whether current instruction in science and mathematics provides suitable preparation for all technologists" (p. 109).

Within this context of renewed political interest in science and technology education, the then Department of Education established the Technology Education Project "to improve the technological literacy of students and teachers" (Department of Education, 1988, p. 3). The project was launched in July 1988 with a national course for 11 teachers, representing most curriculum areas. Course outcomes included a model for technology education and a case for the introduction of technology education into the curriculum. Technology education projects, principally involving technical Lego, were started in some schools. As part of the Project, the Research and Statistics Division of the Department of Education undertook to conduct a survey of form 3 (13-year-old) students' attitudes towards and concepts of technology. The survey instruments had been developed in the Netherlands (Raat, de Klerk Wolters & de Vries, 1987) through workshops with researchers from over 20 countries in Europe, North America, Africa, and also Australia. Pilot study results were provided fof nine countries. The use of an internationally developed instrument would allow comparison of New Zealand students' perceptions with those of students in countries where technology education had and had not been introduced.

In 1989, when the New Zealand study was undertaken, technicrafts (clothing, home economics and woodwork) were compulsory for all students in the last two years of primary schooling (forms 1 and 2) and science was a compulsory subject from school entry. Thus all students in the study would have experienced a range of technical subjects and science. While all students continued with science in form 3, technical and recently introduced technology-related subjects were optional, and strongly gender-stereotyped. This is shown in Table 1, together with uptake at more senior levels.

TABLE 1
UPTAKE OF TECHNICAL AND TECHNOLOGY-RELATED SUBJECTS AT SECONDARY SCHOOL IN 1989

	Form 3		Form 5		Form 6	
	Girls (%)	Boys (%)	Girls (%)	Boys (%)	Girls (%)	Boys (%)
Clothing and Textiles	28	6	10	(0.2)	4	(0.2)
Home Economics	45	25	18	6	10	2
Engineering Shopwork	3	15	(0.2)	7	-	(0.4)
Woodwork	6	24	1	7	(0.1)	(0.3)
Workshop Technology	1	6	1	20	1	4
Graphics/Technical-Drawing	26	55	4	28	3	18
N	27,453	25,991	31,261	30,415	20,729	221,579

( ) Percentages in parentheses relate to small numbers of students.

METHOD

The Pupils' Attitudes Towards Technology (PATT) questionnaire (Raat et al., 1987) comprised a 60-item Likert-type attitude scale and a 28-item Likert-type concept scale. These scales provided the body of the New Zealand student questionnaire and were preceded by a section seeking biographical information and followed by an open question asking students about their meaning for 'technology'. A teacher questionnaire was developed which sought information about the ability of the students in the sample as ability appeared, from the New Zealand pilot study, to be an important variable.

The PATT attitude scale was developed (Raat et al., 1987) from interviews with 13 and 14 year olds in the Netherlands, and their written responses to open-ended questions. Subsequent factor analysis and the addition of new items including curriculum and career items produced a 60-item scale comprising interest, gender, consequences, difficulty, curriculum and career subscales of 10 items each. Each item has a five-point response format from strongly agree, through neither agree nor disagree to strongly disagree which is scored from 1, negative to 5, positive attitude. In the New Zealand version of this scale some of the items were modified for clarification by the substitution of sophisticated words with simpler ones, the inclusion of explanations (e.g. of the meaning of 'physics'), and highlighting of 'not' in negative items. Nevertheless, a high proportion of girls and boys (over 25%, see Shrigley & Koballa, 1984) still chose the undecided category for 48 and 41 items respectively. This central clustering casts doubt on the validity of these items. High use of the undecided category was noted too by Rennie and Treagust (1989) in a study using PATT items, as was the greater tendency for girls to choose this category. Cronbach's alpha coefficient indicates good reliability (0.84 for the total score, falling to 0.76 for the difficulty subscale) generally better than that reported elsewhere (Raat et al., 1987), possibly because of the larger sample than in all countries but the Netherlands and the improved clarity of the items. However, factor analysis provides poor support for the subscales identified by Raat et al. Factors of interest and difficulty can be identified; two factors contribute to gender concerns and two further factors give some support for consequences and career factors. The factors which take up most of the variance in the present study, universality (30%) and importance (10%) do not appear in the PATT subscales.

The PATT concept scale was originally constructed to express five characteristics of technology, identified in the literature by Raat et al. (1987). These were: "technology is a specifically human activity; technology influences all aspects of society; technology and sciences are interrelated; designing and technical skills play a major part in technology; and the three pillars of technology are matter, energy and information" (p. 10). Factor analysis of pilot study data, however, did not yield these five characteristics and subsequent modification led to four subscales, human activity and society (10 items), technology and sciences (6 items), designing and technical skills (7 items) and matter, energy and information (5 items). The first and third of these were identified from students' essays. Each item on these scales has a three-point response format, agree, don't know and disagree and is scored 1 for a correct response and 0 for don't know or an incorrect response. These items were modified in the New Zealand questionnaire in a manner similar to that used for the modification of the attitude instrument. However, as with that scale, large proportions of students, especially girls, still chose the undecided category. For 24 and 13 items, 25% of girls and boys, respectively selected 'don't know'; see Rennie (1987) for similar observations among Australian students. It is suggested that the large numbers of students making this selection did so because of their poor concepts of technology, which is supported by students' responses in the final sections of this questionnaire and also elsewhere by Raat and de Vries (1987).

Cronbach's alpha coefficient suggests good reliability for the total score (0.89), better than in most countries reported, but lower reliability for the subscales, especially the pillars of technology subscale (0.45) for which students also gave the highest percentage of 'don't know' responses, 36%. Again, factor analysis provides only partial support for the subscales. Factors of people and society, problem-solving or technical process, and science and change approximate to three of the subscales identified by Raat and his co-workers

(1987), and contribute 37%, 13% and 6% of the variance, but the pillars subscale is not evident. The view of technology which underpins these scales, including the restriction of products to artefacts and the exclusion of human input from 'pillars' and the identification of problems and needs from 'human activity and society', also constrains them. Their validity, therefore should be questioned.

A stratified probability sample was drawn to represent the population of form 3 students. Strata were determined by school authority (state, integrated and private) and school type (coeducational and single sex), and the probability of selecting a school was made proportional to the number of students in form 3 of that school. One intact form 3 class was selected at random from all of the form 3 classes in each selected school. The student sample comprised 1,469 students from 62 schools, an 88% response rate.

RESULTS AND DISCUSSION

The results of each of the four sections of the questionnaire are described and discussed. Complete data sets may be found in the research report (Burns, 1990a).

Student Characteristics

The sample closely matched the form 3 population on the stratification variables and also for gender (49% were girls) and for Maori and non-Maori students (17% were Maori). Technical subject choice was strongly gender-stereotyped with two-thirds as many girls as boys taking a 'male' technical subject and over twice as many taking a homecraft subject.

An ability score was calculated for students in each class using, as baseline data, the teacher-administrator's estimate of the ability of the class in relation to other form 3 classes in the school. These estimates were then modified to make ability relative to students in other schools in New Zealand (unpublished results, Parkin, 1989). Thirty seven percent of students appeared in the above average and only 23% in the below average category; and 40% of boys, but only 34% of girls were in this category. These results suggest that teachers' perceptions were biassed toward positive perceptions of their students, particularly their male students.

Attitudes Towards Technology

While recognising problems of validity of items and subscales, comparison with the earlier data indicates that the attitudes of New Zealand students tend in the same directions as those of students elsewhere. Girls have more positive attitudes than boys toward non-stereotyped gender roles in technology (namely, that girls as much as boys have the interest and ability to do technology). Girls also perceive technology as being easier than boys do. Boys are more interested in technology and generally see technology in the curriculum, as a career and in its consequences more positively. Despite compulsory technology education in some countries, actual scores on the attitude scales were little different from those in New Zealand where it is not compulsory; indeed, in Poland, where the history of technology as a separate and compulsory subject was longest, attitudes were among the least positive. These data also suggest that students in New Zealand are more highly sensitised to gender issues and concerns about the consequences of technology than students in Poland. Clearly, the nature of the technology education is critical in developing attitudes to technology.

Several other variables beside gender were related to attitudes toward technology in the New Zealand study, most notably teacher-perceived ability. Students of higher ability had less gender-stereotyped attitudes and saw technology as easier than lower ability students. For all other subscales, while high ability students had more positive attitudes than students of average ability, attitudes improved again with lower ability students, perhaps because technology appeared close to the technical subjects with which they traditionally identified. This relationship between ability and attitudes makes it difficult to identify relationships between attitudes and other variables where ability is a possible mediating variable. Maori students have higher interest in technology than European students and are more likely to see it as a career possibility, but they are also more likely to gender-stereotype technology and see it as more difficult than European students. The parallel between Maori and European and low ability and high ability comparisons and the perceived low ability of Maori students suggests that the attitudes of Maori students are more a consequence of ability than ethnicity. Similarly the highly positive attitudes of boys in single-sex schools may be related to their perceived above average ability rather than to their school type.

Concepts of Technology

When New Zealand students' total concept scores and scores on all four subscales were compared with data for other countries, there was little difference between countries, except for Poland where scores were generally higher. Similar differences occurred between girls and boys, with boys usually scoring higher, again except in Poland. New Zealand students on average answered only half of the questions correctly, but they scored better on the skills subscale, for which they also had the lowest proportion of 'don't know' responses. In the New Zealand study, ability was related to concepts even more significantly than to attitudes such that students with higher ability had better concepts of technology. Other variables included ethnicity and school type, but since these variables interacted with ability interpretation was again difficult.

The strong relationship between ability and concepts and between ability and attitudes suggests that concepts and attitudes are correlated, and indeed Pearson correlation coefficients of .43 and .51, significant to $p \leq .0001$, were found between total concept and attitude scores for girls and boys respectively. And significant correlations were found between total concept scores and scores on each of the attitude subscales for both girls and boys. While it is likely that such relationships should exist it is important to appreciate that students with better, that is broader, contemporary views of technology do indeed feel more positively about the subject.

Meaning for Technology

This open question asked students to say what 'technology' meant to them. Since this question followed the attitude and concept scales, responses would have been influenced by those scales; but comparison with international results was seen as a priority and this order was chosen to avoid the expression of a meaning that could have constrained responses to the scales. Responses were analysed following a grounded theory approach (Glaser & Strauss, 1967) and are summarised in Table 2. Preparation of the summary was guided by a view of technology developed within technology studies (see Layton 1986, 1988) and includes the preparation of a product (artefact, system or environment) to meet a societal problem or need and the evaluation of the effectiveness of that product. The sample for the analysis of this question was smaller than for analysis of the earlier sections, and comprised 6% more students from coeducational schools and 1% and 5% fewer students from single-sex girls' and single-sex boys' schools respectively. Once again, more girls than boys expressed doubt about the nature of technology; but those girls who did provide a meaning gave more extended answers.

TABLE 2
GIRLS' AND BOYS' MEANINGS FOR TECHNOLOGY

Meaning	Girls (%)	Boys (%)
Recent *(new, modern)*	70	60
Part of human history *(old and new)*	4	4
Products *(machines, computers, drugs)*	60	48
Problem-solving process *(improving, inventing)*	32	37
Technical process *(making, fixing)*	20	16
Scientific process *(investigating, discovering)*	16	16
Benefits *(better lifestyle, cures disease)*	39	40
Harms *(pollution, unemployment)*	16	16
Universal *(part of everyday life)*	26	18
Don't know	20	8
No response	4	4
Responses including five or more points	29	22
N	641	592

Overwhelmingly, students saw technology as a recent phenomenon (for example, as 'new inventions', or 'for the future') and as artefacts (for example, machines, computers, microwave ovens, cars, drugs). Girls entertained this view slightly more than boys. Few girls or boys saw technology as an integral part of human history. A typical comment was:

> Well I think technology has a lot to do with computers. But I really don't know much about technology, so it's hard to put what it means to me, in everyday life. I haven't really thought about it. But I always thought of technology as being computers, and electricity. (girl)

Approximately one-third saw technology as a problem-solving process, involving improving and especially inventing things. Fewer saw it as a technical process, or as a scientific process; but it was common for these students to see more than one process involved. The following student saw technology as both a problem-solving and a scientific process.

> It means the inventing of new and improved objects to make our lives more comfortable also it means we can know more about the world around us. (boy)

More girls than boys appreciated the involvement of technology in everyday life, presumably the use of 'hi-tech' gadgetry since this was students' main conception of technology. However, there was no difference in perceptions of the way in which technology affects society. More girls and boys thought technology was beneficial than thought it was harmful, and small proportions, 7% of girls and 5% of boys, expressly gave a balanced view.

> Sure, 'technology' can help us in many different ways, i.e. microwave oven. However, this same technology could destroy us. Although nuclear arms have come to a truce (at the moment) wars involving technology unknown 100 years ago still kill our fellow man. If we add it all up, I think we should continue to develop technology. (boy)

Despite such more sophisticated comments, the limited view of technology, expressed by most students, supports the low scores obtained on the PATT concept scale. Few students would have been able to recognise the view of technology advanced by Raat and his co-workers (1987).

IMPLICATIONS

Students' positive attitudes toward technology provide a favourable context for the introduction of technology education. But recognition of the nature of those attitudes and their relationship with students' concepts of technology and their ability, gender and ethnicity is important for the implementation of an appropriate curriculum.

Contemporary view of technology through history of technology

While there can be no argument about the need to underpin any curriculum with a contemporary view of technology, it is essential to realise that most students hold a limited view of technology in which technology is synonymous with recent technological products. In any curriculum it will be necessary to extend students' views to accommodate an appreciation of the nature of technological processes, especially their social context. It is suggested that this may best be accomplished through study of the history of technology.

Technological process

Though technology as a process rated a far lower profile with students than technology as a product, where it was recognised, students entertained a range of understandings of that process, as technological, scientific and technical. It is essential that the distinctive character of technological activity, including creative problem-solving and design, be appreciated so that the intellectual challenge inherent in technology is addressed. There is the opportunity to explore and develop the contribution of tacit knowledge and initiative thought.

Cultural location of technology

The benefits and harm accrued to society as a consequence of technological developments were recognised by a significant number of students, but none communicated an awareness of the origins of technological developments within society. Thus developments come to be seen as inevitable rather than culturally located. It is important, especially for hitherto disenfranchised groups including girls and Maori, that students appreciate the role of human choice in identifying societal problems and in selecting methods by which solutions are sought and evaluated.

Areas of technological activity

Technological products were seen by students almost exclusively as artefacts, generally electrical and mechanical. Such views clearly restrict students' concepts of technology to the possibilities within traditional European, male technical areas. It is important to extend content areas to include, among other things, food, textiles, ecology, health, economics and education. These areas not only allow different practitioner knowledge to be valued, but also extend the likely products to include systems and environments, more fully implementing a contemporary view of technology and making technology accessible to a wider range of student groups.

Equity in technology education

Girls, and to a lesser extent boys, saw technology as equally interesting and accessible to girls and boys. The potential is available to create a new subject that succeeds (as information technology has failed) in providing equitable education for both genders. To do so needs recognition not only of the cultural location of technology and the wide range of areas within which technology is practised (as indicated above), but the different interests, values and learning styles of girls and boys, in effect their different pedagogies. Such different pedagogies (Kruse, 1992) exist also for Maori and European students and similar recognition is required to provide equity in technology education for Maori.

Such a curriculum would be empowering. Students would be able not only to solve technological problems, but to recognise the role of technology in society and appreciate that people can choose the sort of society they want. The indications are, however, that government belief in technological development for economic growth will steer technology education toward skills training for a flexible workforce. The foreword to The National Curriculum of New Zealand (Ministry of Education, 1991) makes clear its overall goal "to enable (young New Zealanders) to compete in the modern international economy" (not paged). It would suggest that there will be pressure to narrow the focus of technology education to technological capability and particularly to the skills to design and make artefacts for the marketplace. The breadth that would encourage a wider range of students into technology and, ultimately, give them control over their own destiny will be lost. People will become pawns in a game led by a fickle market.

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REFERENCES

Beattie, D. (Chairperson) (1986). Key to prosperity: science and technology. Report of the Ministerial Working Party. Wellington: Government Printer.

Burns, J. (1990a). Students' attitudes towards and concepts of technology. Report to the Ministry of Education, Wellington.

Burns, J. (1990b). Public attitudes towards and understanding of science and technology in New Zealand: implications relating to women. Report to the Ministry of Science and Technology, Wellington.

Cosgrove, M., Newman, B., & Forret, M. (1987). Teaching technology - refrigeration, an example from New Zealand's economic history. Science Education Research Unit, Waikato University, Hamilton.

Department of Education (1981). Education statistics of New Zealand. Wellington: Government Printer.

Department of Education (1987). The curriculum review: report of the Committee to Review the Curriculum for Schools. Department of Education, Wellington.

Department of Education (1988). Technology education project. Technology Newsletter No.1. Department of Education, Wellington.

Glaser, B.G., & Strauss, A.L. (1967). The discovery of grounded theory: strategies for qualitative research. Chicago: Aldine.

Green, W. (1984). Science, technology and society education. Proceedings of the 4th New Zealand Science Teachers' Conference. Wellington, 6-12.

Kruse, A-M (1992). '... We have learnt not just to sit back, twiddle our thumbs, and let them take over.' Single-sex settings and the development of a pedagogy for girls and a pedagogy for boys in Danish schools. Gender and Education, 4, (1/2), 81-103.

Layton, D. (1986). The technological imperative. School Technology, 20, (1), 10-11, 29.

Layton, D. (1988). Revaluing the T in STS. International Journal of Science Education, 10,(4), 367-378.

Longbottom, J. (1984). Why science: the views of a heretic. Proceedings of the 4th New Zealand Science Teachers' Conference, Wellington, 36-42.

Ministry of Education (1991). The National Curriculum of New Zealand: a discussion document (draft). Department of Education, Wellington.

Raat, J.H., de Klerk Wolters, F., & de Vries, M. (1987). Report PATT Conference 1987, vol.1 proceedings. Eindhoven University of Technology, Eindhoven, The Netherlands.

Raat, J.H., & de Vries, M. (1987). Technology in education: research and development in the project 'Physics and Technology'. International Journal of Science Education, 9, (2), 159-168.

Rennie, L.J. (1987) Teachers' and pupils' perceptions of technology and the implications for curriculum. Research in Science and Technological Education, 5,(2), 121-133.

Rennie, L.J., & Treagust, D.F. (1989). Measuring students' attitudes and perceptions about technology: a multidimensional concept. Research in Science Education, 19, 221-230.

Shrigley, R.L., & Koballa, T.R. (1984). Attitude measurement: judging the emotional intensity of Likert-type science attitude statements. Journal of Research in Science Teaching, 21, 111-118.

Walsh, B. (ed.) (1987). CERTECH: The secondary-tertiary student flow 1979-1986; and the implications for a changing economy. Palmerston North: Massey University.

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CLASSROOM BEHAVIOUR SETTINGS FOR SCIENCE: WHAT CAN PRE-SERVICE TEACHERS ACHIEVE?

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ABSTRACT

Routines are a fundamental aspect of classroom life and much attention in recent years has focused on routines for management. The concept of 'behaviour settings' and transitions between them as classroom routines is explained and exemplified. This view of routines provides an explanation for the difficulties faced by relieving teachers and student teachers who enter classrooms at mid year and suggests how new routines for complex science activity may be introduced.

In this research three pre-service teachers, who have collaborated with the researcher, endeavour to describe present class routines and develop new ones to allow complex science learning experiences to be planned. Their success is evaluated from data collected from interviews with these teachers, their associates, their students and from classroom observation. The work suggests ways of helping teachers innovate constructivist approaches in their classrooms.

BEHAVIOUR SETTINGS AND ROUTINES

Management has long been an issue of special interest to science and technology teachers and an area of special concern for beginning teachers. Teachers know from experience what studies now confirm: the importance of establishing management routines at the beginning of the year in and maintaining these for the remainder (Emmer, Evertson & Anderson 1980; Evertson & Anderson 1979; Doyle 1984; Reynolds, 1992). Leinhardt, Weidman and Hammond (1987) provide a vivid description of how six expert teachers establish routines in the first week of school, introducing half to 3/4 of them on the first day. More than 80% of these routines were evident at mid year. Their work also suggested few routines were introduced after that early period.

If routines are so much a part of classroom life —and in this study the classrooms and teachers involved provided overwhelming evidence of their importance to them —how best may we categorise and describe them?

In a detailed study of one teacher, Yinger (1977) developed the concept of *activity routines* as "controlled behaviour settings in the teacher's planning and instruction" and *management routines* as the procedures for transitions between activities, handling equipment and entering and leaving the room. The distinction between activity routines as behaviour settings and management routines which are focussed on transitions is very useful. Transitions between activities have long been recognised as a potential source of chaos in classrooms (Kounin, 1970) and efficient transitions as a feature of the classrooms of expert teachers in primary (Kounin, 1970; Doyle, 1984) and secondary schools (Treagust, 1991) in which superior academic learning may occur.

The notion of *behaviour settings* is derived from ecological psychology. Barker (1963) in an address to a conference took the opportunity to illustrate the concept by referring to the assembly he addressed in a hotel room. In this context a behaviour setting:

- occurs at a place within spatial boundaries and within a time frame: what happens outside the walls is different from within. When the allotted time elapses there is a transition to morning tea; a very different behaviour setting where roles are rather different.
- consists of a group of people; all have roles. These are accepted and understood before the setting began.
- has props such as chairs (all facing one way except two), an OHP and papers.
- is part of a nested structure; it exists within a larger conference and within it could be nested mini settings. (For example two may sit chatting at the back.)
- is "independent of its personnel" in the sense that removal or replacement of any of those present would not affect what happens to the types of roles and interactions of the setting.

In a behaviour setting we share some goals, but are certainly part of it for our own purposes and for these we endeavour to maintain the setting. Anyone who behaves inappropriately is pressured by others to mend their behaviour, or if disruptive enough, even excluded. Each participant has opportunities within the setting and obligations to maintain the setting. We are likely to make special efforts to maintain the setting if it becomes underpopulated (Wicker, 1976). In an important sense we share the setting and negotiate its continuity.

Classrooms provide a rather obvious example of such settings (Gump, 1969). Given this view the role of a class reliever or student teacher walking in to take over a role in established behaviour settings becomes invidious. They are likely to behave inappropriately to the setting and be pressured to conform. When that doesn't happen they may be effectively excluded.

However when we consider the variety of activity in our most interesting classrooms, to merely label a classroom as a 'behaviour setting' is not enough. To put these ideas in a science teaching context let us consider a classroom in which the 'interactive approach' (Biddulph & Osborne, 1984) is operating. From a class conversation about the topic (before views) the students would move to exploratory activities perhaps in groups, then be reassembled to brainstorm and discuss questions with the teacher as recorder. Subsequently the class may be found conducting individual or group investigations using several sites while the teachers consults, monitors and assists. Each of these activities involves students and teacher in quite different roles and is therefore a distinct behaviour setting. Even within a single science lesson it is quite likely there will be an introductory stage (settle down; this is what is on today ...), a practical activity stage, a 'conversation' stage and a 'write about it' stage. Again between each stage roles and expectations change markedly.

The participants may have labels for their routine settings. 'Activity groups' commonly describes the setting in science classes in which students work together in their 'usual group' of three or four to carry out practical activities. It is useful to distinguish routine behaviour settings from the **tasks** which may be accomplished within them (Doyle & Carter, 1984). The 'Activity groups' setting may include tasks such as following instructions, obtaining equipment, planning investigations, brainstorming ideas, preparing a display ... Tasks may also be routinised.

One way in which this analysis of routines for science teaching is particularly useful is that it suggests how the complexity and sophistication of science tasks and settings may be enhanced by elaborating and integrating settings and tasks to increase student responsibility and the variety of activity that is routinely possible. It is not too difficult to imagine the gradual amalgamation of the segments in a structured lesson into more sophisticated settings in which chaired discussion, decision-making, problem-solving and report-planning are merely routine aspects of the 'activity groups' routine. The use of structured lessons to develop new settings and introduce new tasks which can later be elaborated and integrated, is the suggestion the participants in this collaborative research exercise took with them to their classes.

However this view of routines also provides a daunting challenge to preservice student-teachers who enter classrooms well after routines are established, expected somehow to learn how to manage their own classroom. That many do not, and subsequently struggle through the early months of their teaching career is well documented and apparently accepted as inevitable by many teachers and teacher educators (Ryan, 1986; Pearson, 1987).

THE PRESENT STUDY

This analysis of routines and the difficulties it suggests for by student-teachers going to teaching experience at mid year raise the questions this research set out to address:

- Can classroom practice be described using this view of routines?
- Can student teachers add new routines to those operating in a class by elaborating and/or integrating existing routines?

Procedures

Three students were selected from the class of a current third year (graduating) science education group who were posted to schools close enough to visit for observation and seemed likely to succeed in the situation because they had demonstrated good understanding of course ideas. All were posted to junior classes with very capable teachers and all agreed to collaborate in the current research study in which they endeavoured to establish new routines with their class. Their associates and the children also agreed to participate.

Several teaching sessions taken by each of the student-teachers were observed in an effort to produce a running description of events, in as much detail as possible; particularly the teacher's actions related to management, routines and children's behaviour. The teachers were provided with this observer's record to scan and comment upon after each observation. In one case a record of the morning class taught by an associate teacher was similarly made. Each class was observed for at least two hours on four to six separate occasions over the five week period of the student teacher school posting. Each student-teacher agreed to keep a diary of notes and reflections about their progress, especially those related to this project. They also provided their own description of current classroom routines and their plans for establishing the new routines. A post-section interview was conducted with two of the student-teachers and notes based on lesson observations by their associates were made available.

Each associate was interviewed on audio-tape twice, first about their routines and their views about routines, and later post-section interviews were conducted to ascertain their perceptions of routines introduced by the student teacher. In one school where routines were a matter of school policy the senior teacher of junior classes was interviewed to ascertain the policy and action she takes in the induction of new teachers early in the year. Several children were also interviewed about 'what you usually do'.

The observations, transcriptions of the audio-taped interviews and teachers perceptions, as is usual in this type of research, offer a rich selection of interesting data. In seeking evidence related to answers to the questions of the study, evidence was considered valid if the perceptions of observer, student-teacher and associate (plus in some instances students and senior teacher) are in accord. Mention is made of any disagreement in the discussion.

RESULTS AND DISCUSSION

Case Study One

Alison was posted to a Grade 2 (six year olds) class in a school in a lower socio-economic area. Her class included children from a range of backgrounds and of varied abilities. Four were identified as having "special needs" including a boy for whom English is a second language. Alison and her associate, Ms M, were about the same age, and they were very compatible, quickly establishing a relationship of mutual respect.

Alison took her collaborative research role seriously and provided a fairly detailed description of classroom routines in the first week. These were very clear in this classroom; they could be observed, they were perceptively described by Alison, described in detail by Ms M and discussed by the senior teacher of junior classes. All junior classes under her leadership established the same basic routines at the beginning of the year.

An analysis of routines based on behaviour settings and transitions fitted this classroom very easily. Ms M's description of her own class routines included most of the labels for behaviour settings used below. She responded to the term "settings" used in interview and discussed various activities and tasks carried out in each setting. Her senior colleague regarded routines as primarily a management technique but stressed their importance for good management and the children's sense of security. The classroom behaviour setting routines were:

* 'Teams on the mat': Children in team lines seated (with arms folded to "show they were ready"). Morning and afternoon sessions were initiated here with a story "to calm them down" (Ms M). Reading a "big book" or from a flip chart, introduction to writing and transitions inside to outside used this setting routine. The teacher sat on a large chair referred to in the observation notes as the "throne". Team leadership rotated each day. Props varied; easel or travelling blackboard may be used. Individuals may stand up to read or perform.

* 'In a circle on the mat'. Children seated in a circle; teacher joins the circle usually kneeling. Used for "class sharing", for various language or maths games and for

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previous science activities. 'Sharing time' uses a 'talking stick' - if you are not holding it, you are a listener.

- 'At our desks'. Each child has an allocated place at one of the large tables. They are not in teams. Writing, art activities and silent reading occur in this setting.
- 'Free choice'. Children at various designated sites in the classroom doing activities of their choice. Used when writing, reading or maths set tasks are completed.
- 'Reading groups'. Special reading groups at specific activities. Cross grouped with other classes. A daily routine before and after 'morning play'.
- 'Reading in teams'. Reading activities carried out at specific sites in the room such as the 'library', the listening post, the enrichment table, the 'big book rack' and so on. The class work in their teams for this activity.
- 'Maths groups'. These are entirely different groups. Each group works on maths activities from their 'group box', the 'enrichment task' or with the teacher in a rotating sequence.
- 'Buzz groups'. Teams set at designated sites on the floor. Each group has a 'talking stick' (see 'in a circle on the mat' above).
- 'Fitness'. Conducted outside in different sites. "Teams are often useful in outside situations." (Ms M.)
- 'Computer'. Two children at a time work on the computer nearly continuously throughout the day. Turns are indicated on a wall chart; each child introduces the activity to the next.
- 'Hall time'. Physical Education or Music in the hall. "When the music stops the children know to freeze and stop talking. " (Alison.)

Transitions between each of these settings are distinctive management routines. Differences among transitions may seem trivial but are certainly not. The transition from 'teams on the mat' to 'in a circle on the mat' is described by Ms M. "I just say "circle please" and they just know that team five goes that way, team one goes that way and the rest split in half". The senior teacher gave a very similar description of the choreography of this transition.

Most transitions involved 'teams on the mat' to or from another setting. 'Teams on the mat' was usually the setting used for giving instructions or information about the next activity and was always used when leaving or entering the classroom, as a kind of intermediate stage. Most of these transitions were presided over by the teacher on the 'throne' moving one team or group at a time.

There were many management routines associated with the distribution and collection of books and equipment. Team leaders collected crayons and pencils for writing; but individuals placed their writing folders in a set place when their work was approved as completed. Monitors were used for packing 'group boxes' at Maths time and the rotating leadership of the teams was used to provide a person responsible for collecting and returning reading materials.

Alison's particular challenge was to introduce new settings for science activities. She designed them with a similar care for detail the descriptions of the choreography of class routines displays. In a post-section interview, after she has noted the efficacy of her associate's routines she describes her own efforts.

> "The first day I spent most of the science lesson going through that routine which was two behaviour settings: "on the mat" - they know that was time for discussion and they didn't touch anything. Then at the table doing activities ... They weren't allowed to move away but ... they could discuss with each other —use the equipment or do whatever —investigate things, find out, do their own problem solving. But as soon as they came back to the mat that was time for sharing. The first day I spent going from one behaviour setting to the other - that took quite a long time to establish, mainly because I wanted them to work at tables in teams."

Each team was assigned a table (necessitating use of the enrichment table for one team). One member of each team was designated a 'science manager' whose role was to have "first turn" and whose responsibilities included packing up and reporting back. The position rotated daily (the usual team routine). A 'science pattern' of 'teams on the mat' - 'teams at tables' (new routine) - 'report back on the mat' (a modification of an existing activity carried out in the 'teams on the mat' setting) was developed and practised over several lessons.

This new pattern of settings and associated transitions seems well established in the classroom. Ms M says she will continue to use it for science and probably other activities. "Now the routine is set and they know what she wants; they've done these types of science things ... they love that —because they've discovered it themselves —they haven't been told it. When they come back on the mat they're full of it. It's getting better and better. So problem-solving is working well."

Alison's activities were simple but exciting for the children. In their 'teams at tables' (the new setting) they used straws to fill an upturned cup with air. They heated and cooled a bottle with a balloon over its top, built simple bridges, made string telephones and rubbed several samples of cloth with brick "to find out which would be the best material to make new overalls for Emma".

She indicates some goals in her reasons for some procedures. Of the 'science manager' role she says "that was to encourage the sharing". Of "reporting back" she says, "they have to use their own language to tell us what they found out in their group ... they found that quite difficult at first ... to come back and tell the class ... what they saw they expected everyone else to have seen anyway. In fact that's not the case." The six year olds were finding that a tough task and improvement in their performance was slow. These goals are not those mentioned in her planning; they emerged from the situation as consistent goals over the series of lessons. They have an interesting similarity to the school report comments made by teachers in the study by Kirkwood and Symington (1992).

Alison's school experience was regarded as very successful by all of those involved. The children, with her associate's connivance, held a party on her last day; the possibility of a vacancy for next year was discussed. Her "new routines" have been added to the class repertoire.

Case Study Two

Rachael was posted to a new entrant class in a central city school. The enrolment rose to 30 during her five week section. Her Associate Mrs A is a capable new entrant teacher who begins her school day by greeting "my parents" as the children are delivered. Her relationship with Rachael was senior teacher - junior teacher; she provided her student teacher with useful advice and suggestions in the form of written notes. Rachael appreciated these and the opportunities to 'take over' the class which she did for a large part of her school posting. She maintained classroom leadership when Mrs A was absent and allowed the relieving teacher a secondary role.

Mrs A saw the teaching and maintenance of routines as a fundamental part of her job.

> "You've got to think about how you're going to teach them and once they are taught you've got to make sure they are consistently ... established and renewed. With each new child entering the room you've got to continually do it.

Disruption of such carefully established routines is unwelcome.

> "I really think Rachael has had a successful section because she has tuned in to routines. She's been focusing on and very alert to what's actually happening in the room. She's modelled what I've done and that's given her success."

Most of the settings in this classroom are now familiar and won't be described again. Several, however, did not occur in the previous classroom.

* 'Begin the day'. Parents enter, greet Mrs A; she chats, welcomes children. They deposit bags, return reading books, do little assigned tasks, play quietly.

* 'On the mat'. The teacher has her chair. Children arranged in a cluster before her. The travelling board offers a prop for writing, displaying a 'big book', flipchart, children's work, or 'class rules'. Children's performances or the use of children as models could be used in this setting. Singing is a frequent activity, and most instructions and transitions to and from the room use this routine. The teacher's pointer is an essential prop. When it was lost, everyone offered to find it!

* 'Activity centres'. Numerous sites in the room; Wendy house, doll's house, big block box, listening post, 'library', computer, small blocks, games box, toro tub, science table, can be visited by children. Used when writing, printing are judged completed.

A list of settings does not fully capture the extent of routinisation in the classroom. There was a routine sequence of activities in the settings every day. Some were familiar popular routine activities which had a special significance for the class. And there were clear management routines.

The transitions between the settings were just as orchestrated (if rather differently choreographed) as in the classroom described earlier. "On the mat" was once again was used for instructions and as a transition setting between entry to the room and other settings. It was always the assembly point after 'Activity centres' or group activities.

Mrs A's performance in the transition from 'on the mat' to 'seated at tables' was quite spectacular. The children are dismissed in groups from the 'throne', paper and pencils having been distributed by designated children. They get seated at their tables, then Ms A engages in a behaviour I called 'flitting' but she, more appropriately, called 'hovering'. She shifts one child's book while she scans another table; visits three tables rapidly checking each child; at one table she rejects copying, deals with a runny nose, encourages a child starting to write. Within one minute she has interacted with upwards of 20 children and visited four of the five tables. This initial 'hovering' is replaced by slower interactions as the children settle to their task.

Rachael described most of the routine settings and activities, but better showed she had learned them well by carrying them on all day when Ms A was absent. The observers notes show she was not quite as adept at 'hovering' but effectively used the "let's all join in" technique to hurry the transition from 'Activity centres' to 'on the mat'.

Rachael had set herself the goals not only of establishing new settings for science activities but introducing strategies of the 'interactive approach', particularly that of children asking questions. She undertook a series of mini-units; 'snails', 'floating and sinking' and 'worms' and used other science activities for language experience. A science table display (mung beans, the floating and sinking materials, a 'wormery') was frequently visited by children and some of their parents. Asked whether she successfully established any new behaviour settings Rachael admitted,

> "I just ... tried to work out the best way to handle each different activity."

She had used mostly 'on the mat' for instructions and for reading from books about snails and worms; 'in a circle on the mat' for shared activities (e.g. 'Which of these objects float?') and 'seated at tables' for observing snails and worms. The new tasks of 'asking questions' and collecting 'before views' from the children was a sufficient challenge for the teacher. A new setting was too much.

The five week experience was judged by all its participants, Ms A, the children and Rachael to have been most successful. In the post-section interview, Rachael reflectively comments on the importance of routines in the success she felt:

> I think that's what needs to be said (about) teaching practice ... You look for the routines; you model what the teacher does. If you don't —even if it's not what you'd do as a teacher yourself —if it's against things you believe in —your philosophy of teaching ... you want the children to feel at ease because she's had them for so long. For them to feel at ease you need to be doing exactly what she is: almost being her. Then you can manipulate them once you've got that sort of flow. Only slight changes: they don't pick up (and object to) that sort of thing. But it's initially getting those routines that makes it so much easier to teach the children.

Case Study Three

'Linda' was posted to a classroom next door to that of Rachael which received the graduates from the new entrant room. The class included several children with very 'special needs' including one randomly violent boy and one who could not settle without close supervision. Unfortunately as 'Linda' began her section her associate had to assume greater administrative responsibility in the school and 'Linda' had to share the afternoon class with a first year teacher beginning his first part-time teaching post. She was never able to observe the afternoon routines used by her associate although she was able to attend the research interview to obtain his description of classroom routines. The routinised settings were very similar to those of the two classrooms already described.

'Linda' provided a fairly sketchy list of routines and did not clearly distinguish settings. Management of the class remained a source of dissatisfaction and concern for her throughout her section. She expressed dismay and puzzlement that the children did not seem to respond to her use of the class routines as they did for her associate. However, the observation notes record she did not use quite the same cues and procedures for transitions and sometimes displayed inconsistency between the behaviour she told the children was acceptable (and was consistent with current classroom settings) and what she actually did reinforce by attending to some children's demands.

Despite its potential interest the unsatisfactory situation of her posting led to a decision to abandon further research in this case.

CONCLUSIONS

Can classroom practice be described using the idea of behaviour settings and management routines based on transitions between them?

For this group of junior school classrooms this proved a model with a very comfortable fit. The settings were strikingly similar across all the rooms; transitions were also quite similar, though each classroom had its own ways of dealing with equipment.

Can new routines be added to those operating in a class by student teachers?

Alison succeeded in introducing a behaviour setting within the structure of other settings operating in the classroom. Attractive activities were associated with the new setting. She was less successful in routinising a setting outside the classroom. Rachael used existing settings to introduce unfamiliar tasks. The overall impression gained is that like the classrooms studied by researchers cited earlier, the introduction of new behaviour settings is not undertaken lightly in these classrooms by mid year.

The student teachers involved in this collaborative exercise came away firmly of the view that the first priority for success on a school posting is to learn to use the routines of the associate teacher first. In all three cases success did seem to depend on that prerequisite. Having succeeded in 'replacing' the associate without disturbing the settings and other routines, it was possible in two cases to introduce some variation into the familar classroom pattern.

The study provides some evidence for the usefulness of a categorisation of routines based on behaviour settings and transitions between them. Two student-teachers ascribed both the categories **and the obligation to describe routines operating in the classroom** as fundamental to their success.
It is also noteworthy that the routines they described were not restricted to science sessions. In each case new science tasks were incorporated into familiar or elaborated classroom behaviour settings.

There are many opportunities for further work in this area. A similar exercise with preservice secondary teachers for whom management is even more of an issue is currently under way. Possibly of even more interest is the prospect of working with inservice teachers such as the beginning teachers followed up by Fernandez and Ritchie (1992) to help them develop simple settings and tasks, then integrate and elaborate these until complex constructivist science approaches are as routinised as 'reading groups'.

REFERENCES

Barker, R. G. (1963). On the nature of the environment. Journal of Social Issues, 19, 17-38.

Biddulph, F. & Osborne R. (eds), (1984). Making sense of our world: an interactive teaching approach. University of Waikato, Hamilton.

Doyle, W. L. (1984). How order is achieved in classrooms: an interim report. Journal of Curriculum Studies, 16 (3) 259-277.

Doyle, W. L. & Carter C. (1984). Academic tasks in classrooms. Curriculum Inquiry, 14:2, 129-149.

Emmer, E., Evertson C., & Anderson L (1980). Effective classroom managemen' at the beginning of the school year. Elementary School Journal, 80 (5), 219-231.

Evertson, C. M. & Anderson, L. (1979). Beginning school. Educational Horizons, 57, 164-168.

Fernandez, T. S. & Ritchie G. (1992). Reconstructing the interactive science pedagogy: experiences of beginning teachers implementing the interactive science pedagogy. Research in Science Education, 22, 123 - 131

Gump, P. U. (1969). Intra-setting analysis: The third grade classroom as a special but instructive case In E.P. Willems & H.L. Raush (eds). Naturalistic viewpoints in psychological research. New York: Holt, Rinehart & Winston.

Kirkwood, V. & Symington, D. (1992). Reporting to parents: science in the context of the total primary curriculum. Research in Science Education, 22, 260 - 262

Kounin, J. S. (1970). Discipline and group management in the classroom. New York: Holt, Rinehart & Winston.

Leinhardt, G., Weidman C. & Hammond K. M. (1987). Introduction and integration of classroom routines by expert teachers. Curriculum Inquiry 17 (2), 135-176.

Pearson, J. (1987). The problems experienced by student teachers during teaching practice: a review of published research studies. Journal of Teaching Practice, 7 (2), 1-20.

Reynolds, A. (1992). What is competent beginning teaching? Review of Educational Research 62 (1), 1-35.

Treagust, D. F. (1991). A case study of two exemplary biology teachers. Journal of Research in Science Teaching, 28 (4) 329-342.

Yinger, R. J. (1977). A study of teacher planning: description and theory development using ethnographic and information processing methods. Doctoral dissertation, Michigan State University, East Lansing, Michigan.

Yinger, R. J. (1980). A study of teacher planning. The Elementary School Journal 80 (3), 107-127.

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THE IMPORTANCE OF SELECTED TEXTBOOK FEATURES TO SCIENCE TEACHERS

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ABSTRACT

This paper reports the results of a study of teacher opinions about the features considered important in an ideal textbook. A survey of Queensland high school teachers revealed that they favoured texts that focus on student cognition and which provide useful features such as exercises and practical activities. Differences were found between the preferences of Queensland teachers and the preferences of teachers reported in two American studies. The significance of these differences for writers and publishers is discussed.

INTRODUCTION

Despite many experts advising against a textbook-centred approach to science teaching (Memory & Uhlhorn, 1991) science textbooks are widely used in science instruction (Chiappetta, Sethna & Fillman, 1991; Harms, 1981; Exline, 1984; Elfick, 1984) and, according to Yore (1991), they will continue to have a high profile. Textbooks have a considerable influence on what and how teachers teach and what and how students read and learn. In an analysis of the science reading issue Yore (1986) identified six research foci and related interactions that he believes need consideration. They are: the nature of science, the nature of scientific text, the nature of the reader, the nature of the reading process, the knowledge and attitudes of science teachers, and the uses of science textbooks.

Teachers' attitudes towards and opinions about junior science textbooks were the focus of this study. In particular the study sought to determine what features of science textbooks teachers consider to be important. It also sought to identify the common needs or big ideas that underpinned their choices.

The question of what teachers look for in a science textbook is particularly important in Queensland which has in place a system of school-based program development and assesssment. It is the teachers of a school who choose a textbook to be used by their students. No external bodies give advice on the selection of textbooks. Thus a comparison of the features identified by classroom teachers and the features of textbooks considered important by experts should prove enlightening to textbook writers, curriculum designers, publishers and other educators.

REVIEW OF RELATED LITERATURE

The characteristics that are considered to be important in textbooks have been studied from two perspectives: from the viewpoint of experts based on theoretical considerations and from the viewpoint of the teacher, based on personal practical requirements.

Recommendations from experts fall into two groups: those that refer to big ideas and those that refer to specifics.
Chiappetta, Sethna and Fillman (1991) believe that there needs to be a curriculum balance in textbooks between scientific literacy and science, technology and society. Anderson and Armbruster (1984) have suggested four important general characteristics for textbooks: a structure (that conveys the informative purpose; coherence (so that there is a flow of meaning); unity (so that only one idea at a time is addressed); and audience appropriateness (so that the text fits the knowledge base of the reader). A number of workers have counted and commented on the plethora of terms used in science texts (Merzyn, 1987; Vachon & Haney, 1983; Yager, 1983) and have called for a reduction in the number of concepts presented.

At a more specific level writers have identified a long list of features considered to be characteristic of good textbooks. They include readability (appropriate type face, underlining, italicising, word density, layout, interest and linguistic complexity) (Knutton, 1983); the inclusion of many concrete explicit examples, simplified explanations, consistent organisational patterns in chapters, content compatible with students' prior knowledge, absence of clutter and meaningless jargon (Holliday, 1984); the inclusion of chapter summaries, solved problems, end-of-chapter problems, problems in the text, answers to problems and suggested experiments (Brattin et al., 1982). In an analysis focussing on inquiry, Tamir (1985) checked for the existence in textbooks of features such as a history of ideas and discoveries, personal and social backgrounds of researchers, the formulation of problems, the description of experiments and the presentation and interpretation of tables, graphs and photographs.

There is a certain amount of debate about the utility of illustrations. Kozma (1991) reported that research indicates that pictures have a positive effect on learning especially for poor readers. Holliday (1990) on the other hand cautioned against "the widespread use of fancy decorative photographs (which) merely add pages to science texts without necessarily clarifying important science concepts and processes". Instead he advocated the use of elaborative visuals to reiterate and reinforce information and summarising visuals such as diagrams, tables and flow charts.

It has been observed that the beliefs of teachers about science textbooks do not match the sort of contemporary research findings entioned above (Yore, 1991). This is supported by the findings of a number of studies of teachers' preferences for various text features. Yore found that most teachers believed titles and headings were useful for reading comprehension. Yore and Denning (1989) reported that science teachers identified (in order of frequency) chapter summaries or reviews; a good glossary; questions at the end of a passage or section; higher order questions; underlining, highlighting or bold print; relevant examples; solved and unsolved problems; exercise questions throughout chapter; and objectives to be important features. Spiegel and Wright (1984) found the ten features considered most important by biology teachers were (in order of importance): figures and diagrams; bold face type; real life references; charts, tables and graphs; a glossary; recent copyright; photographs; inclusion of recent research findings; end-of-chapter study questions; and colour in photographs and diagrams. Comparison of these lists of preferences confirms a finding by Yore and Denning (1989) that teachers do not have consistent expectations from texts.

PURPOSE

The purpose of this research was therefore to determine the importance of various textbook features to teachers of junior science in Queensland. In particular this investigation sought to answer the following questions:

- How important would selected textbook features be in an ideal junior science textbook?
- What common needs or big ideas underpinned the choices made by Queensland teachers?

METHOD

The Instrument

Teacher questionnaires were developed based on the previous work on teacher preferences for textbook features (Yore & Denning, 1989; Spiegel & Wright, 1984). The features obtained from these sources were augmented by the researchers in direct response to current social concerns about multiculturalism and gender equity. The main part of the questionnaire eventually consisted of 40 items. Teachers were asked to indicate on the following five-point scale how important each selected textbook feature would be in an ideal textbook:

"Very important" indicates that this feature of a text should be fundamental to the manner in which the text is developed. It must be used consistently throughout the text.

"Fairly important" indicates that this feature of a text should be important but not absolutely binding. That is, there may be times when circumstances prohibit its usage and you would not object to this.

"Of moderate importance" indicates that you think this feature of a text has merit but it is not essential.

"Of little importance" indicates that this feature could be included but it would be more by chance than design.

"Of no importance" indicates that you have never thought about this feature of a text or that you do not see it as being important in any way for a text.

In addition to the 40 questions, teachers were asked to add any further comments about an ideal text.

Sample

Three, four or five teacher questionnaires were sent (depending on the estimated size of the school) to 250 secondary high schools in Queensland. One thousand questionnaires were mailed in June 1991; teachers in 130 schools returned a total of 390 questionnaires.

Results

Responses were assigned values of 5 through 1 with 5 assigned to "Very Important". Listed in Table 1, in descending order of means, are the means and standard deviations for the 40 items.

TABLE 1
TEACHER RATINGS OF IMPORTANCE OF TEXTBOOK ITEMS

Rank	Item	Mean	SD
1	Exercises for students	4.82	0.45
2	Bold face type to identify key words	4.74	0.50
3	Figures and diagrams	4.71	0.50
4	Level of reading difficulty	4.67	0.56
5	Integration of text, lab activities and problems	4.66	0.62
6	Lab activities included in text	4.65	0.69
7	Real life situations	4.65	0.58
8	End of chapter questions with answers	4.62	0.71
9	Features motivate student to work on own	4.61	0.62
10	Design of the layout	4.57	0.59
11	Scientific terminology	4.52	0.63
12	A glossary	4.46	0.75
13	Charts and tables	4.45	0.62
14	Matches junior science syllabus	4.45	0.83
15	Australian examples	4.43	0.76
16	Graphs	4.38	0.68
17	Self assessment tests for students	4.36	0.81
18	Concepts requiring higher levels of thought	4.35	0.65
19	Summaries	4.26	0.86
20	Number of new concepts per section	4.26	0.76
21	Writing style, tense, person, number	4.25	0.85
22	New scientific discoveries	4.24	0.74
23	Photographs	4.22	0.76
24	Inclusion of student objectives	4.17	0.98
25	Recent research findings	4.09	0.83
26	Cost of textbook	4.04	0.90
27	A pronunciation guide	3.86	0.98
28	Colour in illustrations	3.81	0.92
29	Materials that prep for what follows	3.80	0.97
30	Physical size of textbook	3.75	0.98
31	Balance of males and females in photos and illustrations	3.72	1.19
32	Balance of male and female scientists as examples	3.64	1.22
33	Cross referencing	3.60	0.91
34	Suggestions for extra reading	3.50	0.95
35	Information on careers in science	3.50	0.98
36	Historical items of interest	3.48	0.79
37	Recent copyright	3.47	1.23
38	Study questions at the beginning of each chapter	3.28	1.10
39	Multi-cultural subjects in photographs	3.15	1.09
40	A preview for each topic	3.15	0.89

On cursory inspection the means of many of the items in Table 1 would not seem to be very different. However, when a one-way ANOVA was performed on items 10 and 31 the differences in the means was found to be significant at the 0.01 level (F= 157). Thus there should be significant differences between the top ten and the bottom ten items enabling comparisons to be made between preferred and non-preferred items. Also, for many of the items, the standard deviation was quite large indicating a wide range of views expressed by teachers.

In view of current debate about equity issues, the responses of male and female teachers were separately processed for items 31, 32 and 39, the three items that clearly address these issues. The results are presented in Table 2.

TABLE 2
RESPONSES OF MALE AND FEMALE TEACHERS FOR ITEMS RELATED TO SOCIAL ISSUES

	Males (N=233)		Females (N=143)	
Item	Mean	SD	Mean	SD
31 Balance of males and females in photos	3.46	1.19	4.19	0.99
32 Balance of male and female scientists as examples	3.35	1.23	4.15	0.97
39 Multicultural subjects in photos	2.99	1.10	3.40	1.04

When a one-way between-subjects ANOVA was performed on the data in Table 2 the differences between the means for males and females for items 31, 32 and 39 were found to be significant at the 0.01 level (F= 37.9, 44.09 and 12.93 respectively). It can be seen that, especially for items 31 and 32, the mean for female teachers is considerably higher than that for male teachers.

DISCUSSION

One of the aims of this study was to identify the big ideas that underpinned teachers' preferences in text characteristics. In Table 1 the 10 items rated highest by teachers shared some interesting similarities. There were a number of items, such as 'exercises for students', 'figures and diagrams', 'laboratory activities' and 'end of chapter questions with answers', that teachers could immediately use in their classroom practice. We call the big idea underpinning these preferences Teacher Utility.

Other items could be thought of as facilitating student learning. For instance 'bold face type', 'a suitable level of reading difficulty' and 'figures and diagrams' could help students better recognise and assimilate important concepts. 'Exercises' and 'end of chapter questions' could help them test their understanding. The underlying idea could be labelled Student Cognition.

There were also items that could be thought of as influencing the attitude of students about information such as 'real life situations' and 'features that motivate a student to work on their own'. This we call Student Affect.

By contrast, of the ten items rated least important, some dealt with issues of social relevance such as 'the balance of males and females in photographs', 'the balance of male and female scientists as examples' and 'the inclusion of multi-cultural subjects in photographs'. Items featuring careers and historical references were rated much lower than those dealing with scientific knowledge. The idea underpinning these features we call Social Issues.

Given the prevalence, in the top 10 items, of items promoting student cognition, it was surprising to find, near the bottom of the list, two items, 'study questions at the beginning of each chapter' and 'a preview for each topic', that prepared students for what followed in a chapter.

Items in the questionnaire developed for this study were based on studies cited earlier with American science teachers. In Table 3 teacher preferences from these studies are compared with the top 10 preferences from the current study.

TABLE 3
COMPARISON OF TEACHER PREFERENCES IN TEXTBOOK CHARACTERISTICS FOR TWO US AND ONE AUSTRALIAN SAMPLE

US Sample	US Sample	Australian Sample
Spiegel & Wright	Yore	Cook & Tulip
1 Figures and diagrams	1 Summaries/reviews	1 Exercises
2 Bold face type	2 Glossary	2 Bold face type
3 Real life references	3 End of section Qs	3 Figures and diagrams
4 Charts/tables/graphs	4 Higher order Qs	4 Reading difficulties
5 Glossary	5 Bold/underline	5 Integrating text etc
6 Recent copyright	6 Relevant examples	6 Lab activs in text
7 Photographs	7 Solved etc problem	7 Real life situations
8 Recent research findings	8 Qs thru chapter	8 End Chapt Q/Answers
9 End chapter questions	9 Objectives	9 Motivation to work on own
10 Colour photos and diagrams		10 Design of layout

A comparison of the American surveys of teacher preferences in text features and those of the current study reveals certain similarities. Of the top ten items in the present study, 'bold face type', 'real life situations' (relevant examples) and 'end of chapter questions with answers' (or end of section) were found in both the Spiegel and Wright and the Yore and Denning studies. 'Exercises for students' was common with the Yore and Denning findings and 'figures and diagrams' was common with the Spiegel and Wright study.

All three studies would seem to highlight a strong teacher preference for features promoting student cognition: not unexpected, since textbooks are designed to help students learn the material. This preference can be seen in the typical comments of Queensland teachers who reported looking for textbooks that emphasise the nurturing of higher cognitive processes rather than recall:

> I feel it has too much content and detracts from the actual process skills of science.

> Not enough higher process questions as exercises or revision questions.

The following response neatly highlights the emphasis on student cognition:

> A textbook should be used as an 'aid' —not as a crutch. It is there to give direction to the student in the following ways: a) for clarification of a topic that the student may have failed to comprehend in class; b) questions to encourage the student's own thinking process and to consolidate information being taught.

These teachers would seem to want textbooks not so much for the knowledge content per se but as an additional means of stimulating student thinking. They see the textbook as providing opportunities for promoting thought through such features as exercises and questions but also facilitating learning through the highlighting of 'real life situations'.

Items that could be seen as favourable to student motivation featured in all three lists. Spiegel and Wright identified 'real life references' and 'recent research findings'. Yore and Denning identified 'relevant examples'. In the present study 'real life situations' and 'features to motivate students to work on their own' were identified. Teachers comments on motivation concentrated on the effect that the current textbook had on students. A typical comment:

> Students do not find the text inspiring. It is rather dry and dull.

An inappropriate level of reading difficulty was identified as a motivation problem by a number of teachers.

> Reading age is far too difficult and layout poor. It 'puts off' the lower ability student and does not give enough down-to-earth examples.

The concept of 'appropriateness' of content (Anderson & Armbruster, 1984) was a clear consideration amongst the Queensland science teachers in the survey. They also saw the need for a textbook that is pitched at the right reading level. An inappropriate level of reading difficulty was identified as a motivation problem by a number of teachers. This could mean that a gap exists between the expectations about reading skills of some writers and publishers and the level of these skills in students perceived by teachers.

Despite the similarity in response of teachers in all three studies, inspection of Table 3 also revealed differences in preferences. For instance the teachers in the Spiegel and Wright study seem to have had greater concerns of a pragmatic nature. The 'newness' of the book was of importance to them. They rated recent copyright and recent research findings highly. In contrast 'recent research findings' (ranked 25th) and recent copyright (37th) were not regarded as very important by Queensland science teachers. The high rating accorded to inclusion of figures, diagrams, charts, tables, graphs, bold face type, photographs and colour in photographs also would seem to indicate that the visual appearance of the book was also important to the American teachers. Could this be because 'textbook publishers have gone to extremes to provide many colored pictures to lure (American) teachers into adopting their textbooks'? (Ruis, 1988).

The teachers in both the Yore and Denning study and the present study seemed to want features that they could use to support their teaching. This need (exemplified by preferences for 'end of section questions', 'laboratory activities' and 'exercises for the classroom and for homework') underpins the comments made by the Queensland teacher who wrote:

> A most suitable text. Good experiments, well set out. Plenty of work. More chapters than needed. Plenty of homework questions.

Inspection of Tables 1 and 3 indicates that teachers place less importance in certain features. For instance, in the American studies, there was a dearth of references to competencies other than cognition, whereas the Queensland study included laboratory activities.

Nor, it would seem, are social issues of high priority for science teachers in considering the features of a textbook. No items that had strong social connotations were in the top 10 of any of the three lists. Indeed, in the current study, features that relate to social issues (items ranked 31, 32, 35 and 39) were rated amongst the lowest in importance. Given the prominence of equity issues in all levels of education over the past 10 years, it would seem surprising that messages about equity carried in science textbooks would be rated so lowly. If teachers believe in equity, one would imagine that a textbook featuring a balance of males and females in photographs and illustrations, a balance of male and female scientists as examples and the inclusion of multicultural subjects in photographs would be considered important.

There was considerable difference in the way that males and females rated these items with females significantly more in favour of gender messages (see Table 2). There was, however, little difference between the way the sexes rated the importance of multicultural photographs. In the free response section of the questionnaire there were relatively few comments about equity:

> It (the textbook) is not very sexist which is good and still, unfortunately, rare.
>
> One of the best texts I have used but still remotely presented. Is this a turn-off for girls especially? Perhaps diagrams, photos, etc. could be more people-centred.

Research indicates the way that males and females are represented in textbooks can be influential (Walford, 1980). As Warren (1988) puts it:

> They can support traditional sex stereotypes or, by representing women as active participants in science, they can encourage female students to participate equally with their male peers.

Some American publishers, at least, are aware of and have taken positive steps to address the problem of equity (Britton & Lumpkin, 1977). The current study would seem to suggest that such emphases however, would have little effect on the textbook choices of many male teachers in Queensland.

CONCLUSIONS

This study indicates that teachers of junior high school in Queensland look for features in textbooks that they see as being of immediate use to them in their classroom practice. They also look for textbooks that foster student cognition, especially the nurturing of higher cognitive processes. They look for features that promote a positive attitude towards science and which motivate students. Many of these big ideas are shared with American teachers. Yet, although the three studies compared in this paper show similarities in findings, there are sufficient differences to warrant surveys being directed to teachers in local regions. One could also infer, from the study, that a textbook imported from one region into another may not be entirely suitable for the new market. Clearly, too, there is great diversity of opinion even within a region. Teachers will value various texts in different ways. The use of multiple texts, as suggested by Memory and Uhlhorn (1991), would seem to be a viable solution to the problem of diversity.

REFERENCES

Anderson, T.H., & Armbruster, B.B. (1984). Content area textbooks. In R.C. Anderson & R.J. Tierney (eds) Learning to read in American schools: Basal readers and content texts Hillsdale N.J. Erlbaum.

Brattin, J., Compton, A., Dukes, R., Hetzel, R., LaBrecque, R., Lehrman, R.L., Little, R., Ramsay, W. & Wilhite, L. (1982). Physics texts: An evaluative review. The Physics Teacher, 20 (8), 508-518.

Brittin, G. & Lumpkin, M. (1977). For sale: Subliminal bias in textbooks. Report prepared for U.S. Department of Health, Education and Welfare. (ERIC Clearinghouse ED 140279)

Chiappetta, E.L., Sethna, G.H. & Fillman, D.A. (1991). A quantitative analysis of high school chemistry textbooks for scientific literacy themes and expository learning aids. Journal of Research in Science Teaching, 28 (10), 939-951.

Elfick, J. (1984). Survey of science texts used in Queensland secondary schools. The Queensland Science Teacher, 4, 36-47.

Exline, J.D. (1984). National survey: science textbook adoption process. The Science Teacher, 51 (1), 92-93.

Harms, N.C. (1981). Project Synthesis: Summary and implications for teachers. In N.C. Harms & R.E. Yager (eds.) What Research Says to the Science Teacher, 3, 113-127 Washington D.C.:National Science Teachers Association.

Holliday, W.G. (1984). Selecting and using science textbooks. Research Matters...To The Science Teacher, 1, 5 National Association for Research in Science Teaching (ERIC Clearinghouse ED 273489).

Holliday, W.G. (1990). Textbook illustrations: Fact or filler? The Science Teacher, 57 (9), 27-29.

Knutton, S. (1983). Chemistry textbooks: are they readable? Education in Chemistry, 20, (3), 100-105.

Kozma, R.B. (1991). Learning with media. Review of Educational Research, 61 (2), 179-211.

Memory, D.M. & Uhlhorn, K.W. (1991). Multiple textbooks at different readability levels in the science classroom. School Science and Mathematics, 91 (2), 64-72.

Merzyn, G. (1987). The language of school science. International Journal of Science Education, 9 (4), 483-489.

Ruis, S.P. (1988). Something's wrong with chemistry textbooks. Journal of Chemical Education, 65, 720-721.

Spiegel, D.L. & Wright, J.D.(1984). Biology teachers' preferences in textbook characteristics. Journal of Reading, 27 (7), 624-628.

Tamir, P. (1985). Content analysis focussing on inquiry. Journal of Curriculum Studies, 17 (1), 87-94.

Vachon, M.K. & Haney, R.E. (1983). Analysis of concepts in an eighth grade science textbook. School Science and Mathematics, 83, 236-245.

Walford, G. (1980). Sex bias in physics textbooks. School Science Review, 62, 220-227.

Warren, C.R. (1988). The use of ordinary least-squares regression in the development of an instrument to measure sexism in biology textbooks. Paper presented at the annual meeting of the Mid-West educational research association, Chicago, Illinois. (ERIC Clearinghouse ED 300235).

Yager, R.E. (1983). The importance of terminology in teaching K-12 science. Journal of Research in Science Teaching, 20, 577-588.

Yore, L.D. & Denning, D. (1989). Implementing change in secondary science reading and textbook usage: A desired image, a current profile, and a plan for change. Paper presented at the 62nd annual meeting of the National Association for Research in Science Teaching, San Francisco. (ERIC Clearinghouse ED 305270).

Yore, L.D. (1986). What research says about science textbooks, science reading and science reading instruction: a research agenda. Resources in Education Paper presented at the 59th annual meeting of the National Association for Research in Science Teaching, San Francisco. (ERIC Clearinghouse ED 269243).

Yore, L.D. (1991). Secondary science teachers' attitudes towards and beliefs about science reading and science textbooks. Journal of Research in Science Teaching, 28 (1), 55-72.

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DEVELOPMENT OF AN INSTRUMENT FOR MEASURING ATTITUDES OF EARLY CHILDHOOD EDUCATORS TOWARDS SCIENCE

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ABSTRACT

The attitude towards science of first year early childhood education students was explored using an instrument developed for the purpose. The instrument comprises four Likert-type scales, biographical items and two open-ended attitude items. The four scales, characterised as 'confidence', 'enjoyment', 'usefulness' and 'appropriateness of science for young children', were supported by varimax factor analysis and had reliabilities from 0.83 to 0.88. Use of the combined scales as a general 'attitude towards science' scale was supported by principal components analysis; reliability for the combined scale was 0.94. Comments made in response to the open-ended items supported the validity of the scales. For the student group as a whole, mean scores on all scales were slightly to moderately positive, with the highest mean being for the 'science for young children' scale. Students who had studied at least one science subject at Year 12 level had significantly higher scores on all scales than students who had not studied science at senior level.

INTRODUCTION

Given the established correlation between attitudes and behaviour (Ajzen, 1988; Shrigley, 1990), teachers' attitudes towards science can be expected to influence their practice in teaching science. Promoting positive attitudes towards science is a goal of many teacher-training courses, and varying degrees of success have been reported in attaining this goal (e.g. Morrisey, 1981; Lawrenz & Cohen, 1985; Skamp, 1989). However, interpretation and comparison of studies involving science-related attitudes is confounded by the lack of adequate validation and reliability reporting for tests used in some studies, and by the multitude of different attitude constructs measured (Gardner, 1975; Munby, 1980, 1983; Schibeci, 1984). These reviewers distinguish two broad categories of science-related attitudes: attitudes towards science (which include interest in and enjoyment of science, as well as attitudes towards constructs such as scientists and the usefulness of science), and scientific attitudes (scientific ways of thinking, such as open-mindedness). For an attitude measure to be useful in a particular situation, its contents need to be clearly defined and to relate clearly to the purpose for which it is being applied (Ajzen, 1988; Shrigley, 1990). It also needs to have been properly tested on a sample which is roughly comparable to the intended target population (Gardner, 1975).

This paper describes the development and testing of an instrument called Early Childhood Educators' Attitudes towards Science Scale (ECEASS). The stimulus for developing ECEASS was the need for an instrument for assessing the attitudes towards science of students entering pre-service early childhood education courses, in order to evaluate the effectiveness of the courses in promoting positive attitudes towards science, and which could also be used with early childhood teachers for research purposes.

Because available instruments did not appear to adequately cover the relevant dimensions of attitude towards science (identified below), a new instrument was developed.

DEVELOPMENT AND TESTING OF THE INSTRUMENT

Conceptualization of the Attitude Scales.

ECEASS is concerned with attitudes towards science, rather than scientific attitudes. To identify which aspects of attitudes towards science were most pertinent to early childhood educators, a group of second year Diploma of Teaching (Early Childhood) students was invited to discuss their feelings in relation to science. Their comments appeared to fall into three main categories, related to their confidence in science, their enjoyment of science classes (at school and at university), and their perceptions of the relevance/usefulness of science. Because the purpose of the courses being undertaken was to prepare students to work with young children, I was also interested in their feelings about science and science teaching specifically in relation to young children, and encouraged discussion of that aspect. These four aspects formed the basis for attitude scales.

The instrument

Drawing on the range of comments made by the students, eight Likert-type attitude statements were written for each of the four dimensions, to which subjects are asked to respond on a five-point scale (strongly agree, agree, not sure, disagree, strongly disagree). Responses were scored from 1 ('strongly disagree') to 5 ('strongly agree'). Scoring was reversed for negatively-worded items. The scales are listed below. In each case, the first four items are positive and the remainder are negative. Added to these items were six biographical items, seeking information about the course enrolled in, mature age status, gender, science subjects studied at senior levels of secondary school and date of birth.

The sample

The sample for this study consisted of 200 students at the beginning of their first year at the School of Early Childhood Studies, University of Melbourne. Of this group, nearly all (197) were female, 19 described themselves as being of mature age, 122 were enrolled in the Diploma of Teaching (Early Childhood) and 78 were enrolled in the Diploma of Social Science (Child Care Services). Overall, 71% of students had studied at least one science subject at Year 11, and 57% had studied at least one science subject at Year 12. Of this latter group, 77% had studied biology, 16% human development, 11% chemistry, and less than 5% each of physics, environmental science, psychology, computer science, and general science.

Item analysis

Frequency data for individual items were examined to test the spread of responses. Items that produce a narrow range of responses, as indicated by a low standard deviation, are of little use in discriminating between respondents with differing attitudes. Nearly all items had moderate to high standard deviation values (0.72 to 1.15). Only items 11 and 16, having standard deviations of 0.65 and 0.67 respectively, were below 0.70. Item to rest-of-scale correlations were all well above the recommended minimum of 0.30 (Gable, 1986), ranging from 0.49 to 0.68 for Scale 1, from 0.41 to 0.72 for Scale 2, from 0.53 to 0.74 for Scale 3, and from 0.55 to 0.73 for Scale 4.

Confidence in Doing Science Scale I am capable of succeeding in science. I can handle physical science topics such as sound and magnets. I can handle biological science topics such as plants and animals. I feel confident about doing science with young children. I feel nervous about having to do science. I am not smart enough to do well in science. Physical science is too difficult for me to manage. I don't know enough about science to do it with children.	Personal Usefulness of Science Scale I will use science in many ways in my daily life. Science is a worthwhile subject. I'll need science for my future work. Science is useful for solving the problems of everyday life. Science will not be important to me in my life's work. Science is not relevant to me personally. I see science as a subject I will rarely use in future. Science is of no help in day-to day-life.
Enjoyment of Science at School Scale Science lessons at school were exciting. At school I enjoyed learning about how things work in science. The way science was taught at school made it interesting. I enjoyed doing experiments in science at school. At school I disliked lessons about animals and plants. Science lessons about topics like light and sound were dull. Science lessons at school were a waste of time. I found most science lessons at school were boring.	Appropriateness of Science for Young Children Scale. Preschool children can easily do science. Science is a natural part of a young child's life. Science experiences are helpful in promoting development of young children. Young children enjoy science experiences. Science is too difficult for young children. Science is not relevant to young children. Science experiences are of no benefit to young children. Preschool-aged children would be bored doing science.

Scale data

Standard deviations and reliability values (estimated by Cronbach's alpha coefficient) for the four scales are indicated in Table 1. The standard deviation values are satisfactorily close to the expected values for a normal distribution of responses, and the Cronbach's alpha values are all well above the minimum recommended criterion of 0.70 (Gable, 1986), providing some support for the internal consistency of the scales.

TABLE 1
MEAN SCORES, STANDARD DEVIATIONS AND RELIABILITY VALUES (CRONBACH'S ALPHA) FOR THE FOUR SCALES.

Scale	Cases	Mean	Range	Standard deviation	Reliability
1. Confidence	200	27.39	13-40	5.01	0.83
2. Enjoyment	200	26.76	11-38	5.84	0.86
3. Usefulness	200	28.65	8-40	5.05	0.88
4. Young Children	200	29.85	10-40	4.52	0.88
Total Test	200	112.63	45-155	16.85	0.94

Factor Analysis

Varimax Factor Analysis, which identifies groups of items that have variance in common, was used to check whether the items clustered according to the intended scales. The four scales were supported by this analysis, with Factors 1 to 4 clearly identifiable as Scale 3 (*usefulness*), Scale 4 (*young children*), Scale 1 (*confidence*) and Scale 2 (*enjoyment*) respectively. The great majority of items had their highest loading on the intended scale, and the pivotal items for each factor (items with the highest loadings on that factor) were from the appropriate scales. Scales 1, 3 and 4 performed particularly well, with all items having loadings on their intended scales of at least 0.40, and in most cases well above this level. Two items from Scale 2 did not have acceptable loadings on Factor 4: items 6 and 14, which refer to enjoyment of lessons about specific branches of science, loaded highly on minor factors which could be interpreted as 'biology interest' and 'physical science interest' factors. Nevertheless, Scale 2 is satisfactory because of the other six 'good' items and the high scale reliability.

Principal Components Analysis, which examines whether there is one general factor underlying all the items in an instrument, showed that all 32 items had a substantial loading (0.44 to 0.74) on one principal component. This indicates that the instrument can justifiably be used as a single measure of general attitudes towards science in situations where the finer detail of the constituent attitude dimensions is not required. The Cronbach's alpha reliability coefficient for the total instrument was 0.94.

Further Validation

The initial process of using students' comments as a basis for conceptualizing the scales and in the writing of the items for the scales, together with the clear support for the four scales provided by the factor analysis, attest to the validity of the test. Further evidence in support of its validity was provided by the responses made to the open-ended attitude item at the end of the instrument, which asked respondents to comment on their feelings about science. Students who made positive comments had mean scores, on all scales and on the total test, significantly above the mean for all students, and the mean scores for students who made negative comments were significantly below the means for all students ($p<0.001$ in each case). There was no significant difference between means for people who did and did not comment ($p=0.52$ to 0.69).

The actual comments matched the scales quite well and frequently related to enjoyment, interest, usefulness, relevance, importance and difficulty of science, and to science in relation to young children. Contrasting examples of the views expressed are: "Science is a major part of our lives and young children would find it very interesting", from a student who scored 145 on the total test, and: "Young children won't understand it and therefore have no interest", from a student who had a total score of 45.

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REFERENCES

Ajzen, I. (1988). Attitudes, personality and behaviour. Milton Keynes: Open University Press.

Gable, R. K. (1986). Instrument development in the affective domain. Boston: Kluwer-Nijhoff.

Gardner, P. L. (1975). Attitudes to science: a review. Studies in Science Education, 2, 1-41.

Lawrenz, F., & Cohen, H. (1985). The effect of methods classes and practice teaching on student attitudes toward science and knowledge of science processes. Science Education, 69, 105-113.

Morrisey, J. T. (1981). An analysis of studies on changing the attitude of elementary student teachers toward science and science teaching. Science Education, 65, 157-177.

Munby, H. (1980). An evaluation of instruments which measure attitudes to science. In C. P. McFadden (ed). World trends in science education. Halifax, Nova Scotia: The Atlantic Institute of Education.

Munby, H. (1983). Thirty studies involving the "Scientific Attitude Inventory": What confidence can we have in this instrument? Journal of Research in Science Teaching, 20, 141-162.

Schibeci, R. A. (1984). Attitudes to science: an update. Studies in Science Education, 11, 26-59.

Shrigley, R. L. (1990). Attitude and behaviour are correlates. Journal of Research in Science Teaching, 27, 97-113.

Skamp, K. (1989). General science knowledge and attitudes towards science and science teaching of preservice primary teachers: implications for preservice science units. Research in Science Education, 19, 257-267.

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COMBINING ISSUES OF "GIRL-SUITED" SCIENCE TEACHING, STS AND CONSTRUCTIVISM IN A PHYSICS TEXTBOOK

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ABSTRACT

This paper outlines the design of a physics textbook that addresses issues of gender-inclusive physics teaching, STS and constructivism. Difficulties of addressing these issues in a textbook for normal classes, which has to compete with other textbooks on the market will be discussed.

TEXTBOOKS AND INNOVATIONS IN SCIENCE CLASSES

> The content, organization, and development of chemistry texts is greatly influenced by research: market research (Herron, 1983, p.888).

There is no doubt that not only chemistry but science textbooks in general are much less influenced by science education research than by pressures coming from the expectations of those who decide to use them. In Germany, textbooks have to pass a textbook board, which examines whether a book fits the syllabus. Science teachers have choice among the books accepted by the board. Teachers' individual likes and dislikes will then guide the selection. As syllabi are usually written by teachers, and textbook boards are usually staffed by teachers, teachers' preferences determine the quality of textbooks used in schools. Textbooks do not have to fit the actual needs, abilities, and interests of students (that are known, for instance, from research) but teachers' views of students' needs, abilities and interests.

We have written a textbook for students, but made compromises between our "ideal ideas" of contemporary physics instruction and issues coming from market demands. At the moment, we cannot say whether our compromises have gone far enough to be accepted by the decision makers. The evaluation by textbook boards is still taking place.

CHARACTERISTICS OF SCIENCE TEXTBOOKS

Style of writing

Strube (1989) investigated the language of physics textbooks. He summarized his findings as follows:

- Distant authorial voice. The author becomes both remote and anonymous, and consequently the style shows formality and lack of warmth.
- Concern for precision. This leads to a style overemphasizing logical argument, definition, and formal reasoning at the expense of patient concept development.
- Limited context. By rarely straying outside the confines of the specialist use and structure of science, the style becomes rigid, inappropriate to the student's world, and lacking in vivid, figurative language.

- Limited syntax. Alternative, flexible ways of presenting information and ideas are not explored. Definitions are short and easy to remember, while explanations are long, involved, and complex in sentence structure.
- Rhetorical model. A further characteristic of such language - rhetorical model - was also examined. This suggested that the order of presentation of material, at all levels of the text from sentence to whole text, was tradition bound and rigid. (p. 297)

Implicit metaconceptions of science in textbooks

Sutton (1989) focused on the interplay of experiments and theory in science textbooks via investigation within frameworks that stem from the philosophy and history of science. His analysis identifies the following characteristics:

- Science as describing what happens. There is a tendency in science textbooks to focus on describing what happens. According to the implicit textbook message in science, doing appears to be much more important than thinking, especially thinking beforehand. In other words, the message about science is: if the appropriate experiments are carried out, discoveries follow with some certainty.
- Science as data first and theory later. This issue is a corollary of "science as describing what happens". First, data are presented then the theory follows because theory fóllows more or less in a self-evident way, on its own, from data. Sutton presents historical cases here as well as echoes of these cases in contemporary science textbooks. Usually there is no "I" and "we" in science texts.
- Science is presented as being purely rational. It is known from historical cases that scientists usually report on their findings by focusing on the purely rational lines of their thoughts and omitting emotional issues. In textbooks also the rational issue is almost given exclusively attention. The excitement of researchers or their fears about personal consequences and consequences for society are rarely reported in textbooks.

Emphasis on concept definition

Stinner (1992) developed a model for concept acquisition in science (Fig. 1). It contains three planes. The logical plane comprises the finished products of a science, such as laws, principles, models, theories, and facts. The evidential plane summarizes the experiential, intuitive and experimental connections that support what is accumulated at the logical plane. The psychological plane pays attention to issues of students' learning such as the influence of students' preinstructional conceptions. Stinner summarized a textbook analysis on the background of this model in that there is usually a lot of emphasis on the logical plane and that the psychological plane is given almost no attention.

Characteristics of our textbook

The characteristics of science textbooks revealed by Strube, Sutton and Stinner provide frameworks to indicate key features our book intends to highlight. Where the interplay of experiment and theory is concerned the role of experiments is not overemphasized, there is an intimate interplay of thinking (theory) and doing (experiment) instead. Stinner's logical plane is approached through the evidential plane by taking into account the psychological plane. In the style of writing a distant authorial voice is avoided; personal address is emphasized. As far as possible, a style used in popular science books is attempted. To employ a metaphor, our book aims to be a travel guide for the students' journey through the world of physics. It is not just a map for leading a traveller from one place to another in the most efficient way. A travel guide explains the beauty of the landscape, proposes detours, and tells stories about events that took place and so on.

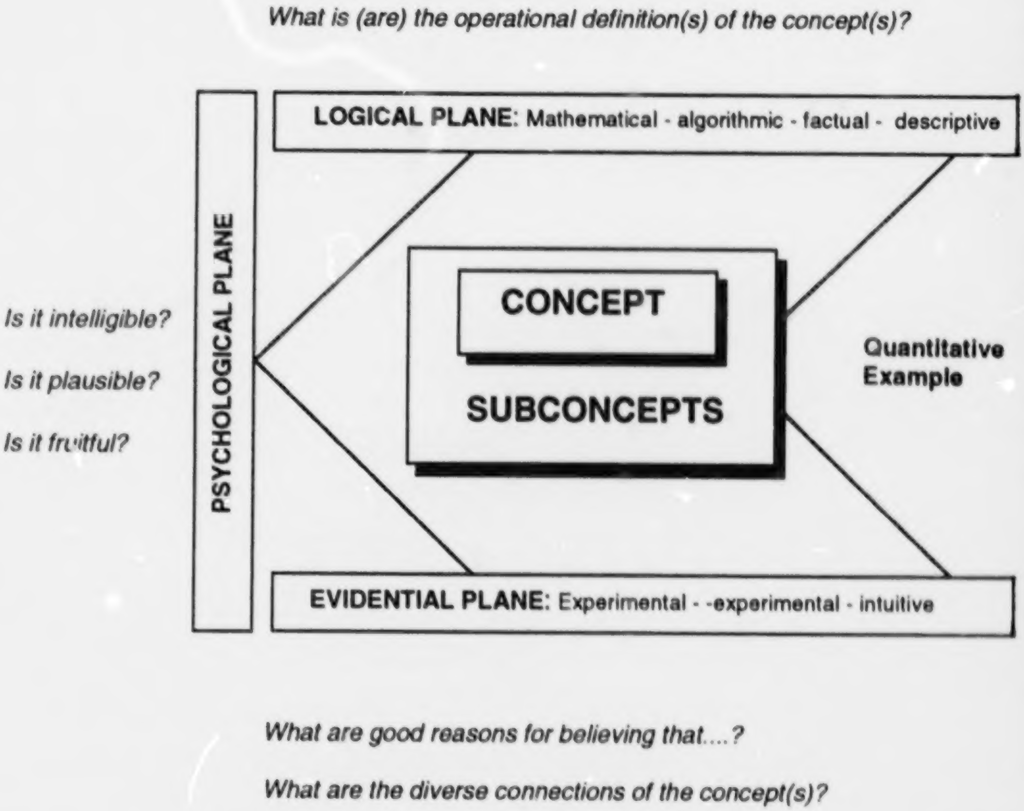
What is (are) the operational definition(s) of the concept(s)?
LOGICAL PLANE: Mathematical - algorithmic - factual - descriptive
PSYCHOLOGICAL PLANE
Is it intelligible?
Is it plausible?
Is it fruitful?
CONCEPT
SUBCONCEPTS
Quantitative Example
EVIDENTIAL PLANE: Experimental - -experimental - intuitive
What are good reasons for believing that....?
What are the diverse connections of the concept(s)?

Fig. 1 A model for concept acquisition in science (Stinner, 1992)

KEY AIMS OF OUR TEXTBOOK

The title of the book is Physics: to understand the world around us (in German: Physik: um die Welt zu begreifen). This is a programmatic title as the key aims indicate:

- The textbook enhances behavior of environmental and human concern.
- Physics is presented in such a way that students acquire insights, abilities and skills that are helpful for understanding and acting in daily life situations.
- Learning starts from students' everyday experiences and conceptions, differentiates and develops them.
- The textbook especially addresses the interests of girls.

In short, the textbook aims at combining the issues that are of primary concern in contemporary science education research and development, namely STS (Science-Technology-Society), gender and constructivism.

On the gender issue

It is known from research on students' interests (Häussler, 1987) that interests, especially girls', continually decline from Grade 7 through 10 (in German schools from about age 13 to 16). However, the studies also provide guidelines that may be used to make physics instruction more interesting for both girls and boys. We tried to take the following guidelines into consideration (Häussler & Hoffmann, 1990):

- Physics that arouses emotions in general stimulates interest. Girls' feelings appear to be stimulated especially by natural phenomena. They are not as much as boys interested in "stunning" technical devices or developments. Examples from our book: colours of the sky, thunderstorms, dance and music.

- Connecting content with issues of daily life stimulates interest, but for girls only if they may rely on their own experiences. Examples from our book: see section below on phenomena in students' life world.

- Interest in dealing with "society issues" in physics instruction is generally high; the interest of girls in these issues increases with age. Examples from our book: noise pollution, saving energy in the household.

- Applications of physics are generally interesting. Girls prefer domains like medicine, living beings (examples from our book: magnetic senses of birds, echo-sounding of bats or fishes, and environmental protection (see next section). Boys are much more fascinated than girls by technical applications.

- Girls prefer issues connected with their own body. There are many examples of this kind in our book: the influence of noise at the human body; effects of electric currents on the human body; methods of accident prevention; characteristics of human senses like feeling heat, seeing and hearing.

- Discovery of physical laws or introduction of these laws as issues for their own sake are not greeted with interest. This is especially true when dealing with them quantitatively. The interest in quantitative physics rises if an application (at least a potential one) is included and the necessity and/or value of quantification is made understandable for the students. Calculations that are an integral part of traditional textbooks therefore are relatively infrequent in our book. If we ask students to calculate something we explain why this is necessary and valuable and we try to choose examples that are greeted with interest like calculation of the braking distance of bicycles and cars or the human daily energy needs obtained from food.

We tried to put the issues listed into practice when writing our textbook. Thereby new perspectives opened up. We do not know how well we succeeded for it is not easy to overcome one's own heritage. Initial reactions of female colleagues have been friendly, but they have also made clear that much more could and needs to be done.

On the STS issue

The contribution of science knowledge towards understanding issues about the interplay of science, technology and society is emphasized. Physics instruction is seen as a major contributor to environmental education as well as to other issues, such as peace education, summarized under the heading of STS.

Topics that have been established as genuine STS issues in physics instruction over the past few years such as nuclear power stations (including dangers of radioactivity in general), heat insulation of buildings, saving energy in general, alternative energy sources and adequate traffic systems are taken up. These topics are given considerable emphasis and are not just appendices to physics concepts and principles. Often the STS topics strongly influence the physics content. For example, the energy concept is not dealt with in a traditional manner. We prefer instead to introduce those basic aspects of the energy concept that may really contribute to the understanding of energy issues in daily life and society. Energy degradation is, for instance, given major attention from an early stage because this idea is a necessary prerequisite in understanding STS energy issues (cf. Duit & Häussler, 1992).

The STS issue not only strongly influences (in some cases even determines) content structures of major parts of our textbook, it appears in side remarks we place at appropriate points throughout the book. When investigating the bicycle in the domain of mechanics there is a paragraph also on the bicycle as an energy- and nature- saving vehicle. Within the topic of surface tension we not only discuss the ability of detergents to reduce surface tension but add a paragraph on chemicals in detergents that may be dangerous for the environment.

Although we emphasize STS issues we want to point out that we do not claim that our book is an STS book. STS plays a major part in the book but we had to find a compromise as outlined above. The "guardians of the physics education establishment" (Fensham, 1987) on the textbook boards, at least, have to tolerate our way of presenting the concepts and principles of their physics.

On the orientation to phenomena in the students' life world

We start, whenever possible and appropriate, from students' everyday experiences and from their everyday conceptions, and try to guide them from there to physics conceptions that may help them to view their everyday world in terms of physics and, hence, to better understand occurrences in their own life. We are aware that there are difficulties involved in this approach. We know from research on students conceptions that quite frequently students' everyday conceptions are contrary to the intended physics conceptions. Therefore, starting from these students' conceptions may be a Trojan Horse, i.e. it may deeply mislead students. We try to address this difficulty by starting from those aspects of students' everyday experiences and everyday conceptions that share major facets with the physics conception.

Despite this difficulty, we have used the approach mainly for the following reason: it is possible to start from facets that are familiar to students, that have something to say to them, that also have to do with feelings and emotions that stem from students' own experiences in daily-life contexts. Girls' interests, especially, may be addressed by such facets. The application of the new conceptions gained to understand students' life-world is a crucial feature. It is not enough to lure students' into the pure world of physics conceptions by starting from their interests. It is absolutely necessary to retain their interest and to develop a positive leaning towards physics in general by making them aware that the new conceptions may help them to understand the world in which they live in another and often more appropriate way.

Everyday tools in experiments

Throughout the book we suggest students' experiments for reasons that are generally accepted and do not need further justification here (cf. Millar, 1989). But we do not rely on the traditional experimental equipment as provided by commercial suppliers; instead, we use tools and materials of students' everyday life whenever possible. Most of these are available in the household, some in ordinary shops at low cost. We were surprised to find that this approach could be almost totally followed through. It is an approach consistent with our view that students should start from their everyday world in order to understand that world. Students may, if they wish, have these experiences on their own and in their life-world context. Physics, then, does not appear to them as something that is valid only for the tools and experiments provided by firms for classroom use only: it is something that has significance for the world outside physics classes.

From everyday conceptions to physics conceptions

The constructivist view of learning as it is used in science education at the moment (cf. Driver, 1989; Duit, in press) comes into play here. Learning is not seen as the transfer of prefabricated pieces of knowledge but as an active construction process on the basis of prior conceptions. Our book intends to play a major part in helping students to construct their own conceptions. We try to stimulate these. We also aimed at writing a book which teachers may find helpful to stimulate students' construction endeavours. Throughout the book our design of content structure was very much influenced by research results of students' pre-instructional conceptions in these domains and of alternative approaches to address the learning difficulties caused by students' conceptions.

Starting from students' everyday experiences in mechanics. There are two complementary ways of addressing students everyday conceptions in literature: starting from aspects of students' conceptions that are already mainly in accord with the science conceptions to be learned; and deliberately arranging cognitive conflicts (Scott, Asoko, & Driver, 1992). In mechanics, we usually prefer the first way of guiding students in a mainly continuous manner to the physics ideas. When introducing the idea of inertia, for instance, we start from students' experiences with carrying a brimful glass of juice. Why is it so difficult to carry it; what happens when you start moving or when you stop? We provide the interpretation that the juice obviously has some sort of persistence. This idea is then tested in another situation, namely experiences when riding a bus. That leads to a more elaborate idea of persistence against changes of both rest and motion. After that, we ask students to ride a bus again but this time to carry the following experiment. A ball is lying in a plate. What happens to the ball when the bus starts, brakes, is driven around a curve and so on? Students are also asked to interpret what they see. The main idea of the strategy we follow has been outlined above. We go through the circle of starting from everyday experiences to understand everyday experiences several times in a spiral-like manner that develops students' intuitive ideas towards the physics ideas.

Explicitly addressing and discussing students' preinstructional conceptions. A key stage in constructivist teaching approaches is to discuss students' ideas before the science conception is presented by the teacher for negotiation (e.g. Driver, 1989). It is, of course, only partly possible to imitate such a strategy in a textbook (e.g. refutational texts have been proven to be quite successful; see the meta-analysis by Guzetti & Glass, 1992, mentioned below).

But at several places we explain the ways most students (and lay adults as well) think according to research findings. Where the particle model is concerned, there is the well-known tendency to attach features of bodies in the macroscopic world to the particles. 'Bodies are hot because the particles are hot' is a paradigmatic example for this way of thinking. We inform students about this misleading idea, for instance, by stating in the textbook: "Some people think (we mean: "you may think") that the tiny particles themselves are hot when temperature rises...." (here an explanation of the physics view that was introduced already before follows).

We address students' alternative ideas about current flow in the electric circuit in the following way. First, we present the model that many students hold before instruction: only one connecting wire is necessary because the current needs only one line to flow from the source to the consumer. We explain to students that this model is quite valuable in that it explains major features of current flow which are so far known by students. But then, we carry out an experiment that causes a conflict. We connect a little motor to the battery. The motor turns left or right depending at the connection to the poles of the battery. We then explain that another model, namely the idea of a closed current flow around the circuit, is able to explain the experiment. In a similar way, we arrange a conflict in order to address most students' alternative idea of current consumption. We think that this kind of strategy is very constructivist in that we never say which model is "right" but try to explain to students which model fits better. We assume that this will lead students to an adequate idea of the "nature" of models, namely to view models as tentative human constructions that fit specific observations but may fail to explain others.

Students as "researchers" of others' concepts. As mentioned, a key idea of constructivist teaching strategies is making students aware of their conceptions and of the differences to science conceptions. At various places in the book, we therefore invite students to ask friends, relatives or others what they think, for instance, what heat is, and to explain to them the physics conception.

To interpret sense experiences that may lead to misunderstandings from the very start in an appropriate way. If one touches a piece of metal and a piece of wood they feel differently warm although they have the same temperature (i.e., a thermometer measuring the temperatures of the two pieces would give the same reading). Most students interpret this sense impression before physics instruction in that the metal's temperature is lower than the wood's temperature. Even after instruction many students stick to this idea. We address this learning barrier by discussing in the chapter on heat, from the outset, major functions of the human heat sense. In general, we put considerable emphasis on interpreting sense impressions (see also section above on gender).

Guzzetti and Glass (1992) carried out a meta-analysis of studies on instructional interventions to promote conceptual change by texts. They come to a quite optimistic conclusion regarding the effects of texts in conceptual change settings. They found that arrangements in science texts that offend preconceptions, and hence create some sort of cognitive dissonance (for instance, by refutational interventions in the texts) are quite successful. For example, they usually result in significantly better results than traditional texts. We are, therefore, optimistic that our ways of addressing students' preconceptions, as outlined above should be successful. So far, we have not carried out any research, but this issue is on the agenda of our research questions we want to follow up as soon as the book is produced and hence available for students.

REFERENCES

Driver, R. (1989). Changing conceptions. In P. Adey (ed.). Adolescent development and school science. London: Falmer Press, 79-99.

Duit, R. (in press). The constructivist view: a both fashionable and fruitful paradigm for science education research and practice. In L. Steffe (ed.), Constructivism in education. Hillsdale, NJ: Erlbaum.

Duit, R. & Häussler, P. (1992). Learning and teaching energy - combining aspects of constructivist, girl suited and STS approaches. Paper presented at the "Science content and pedagogy" workshop. Monash University, Melbourne, Australia, June 29 to July 8, 1992.

Fensham, P. (1987). Physical science, society and technology: a case study in the sociology of knowledge. In K. Riquarts (ed.). Science and technology and the quality of life. Vol. II. Kiel: IPN, 714-722.

Guzzetti, B.J. & Glass, G.V. (1992). Promoting conceptual change in science: a comparative meta-analysis of instructional interventions from reading education and science education. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, April.

Häussler, P. (1987). Measuring students' interest in physics - design and results of a cross sectional study in the Federal Republic of Germany. International Journal of Science Education, 9, 79-92.

Häussler, P. & Hoffmann, L. (1990). Wie Physikunterricht für Mädchen interessant werden kann. Naturwissenschaften im Unterricht - Physik, 34, 12-17

Herron, J.D. (1983). What research say and how it can be used. Journal of Chemical Education, 10, 888-890.

Millar, R. (1989). Bending the evidence: the relationship between theory and experiment in science education. In R. Millar (ed.). Doing science: Images of science in science education. London: Falmer Press, 38-61.

Scott, P., Asoko, H., & Driver, R. (1992). Teaching for conceptual change: a review of strategies. In R. Duit, F. Goldberg, & H. Niedderer, (eds.), Research in physics learning: theoretical issues and empirical findings. Proceedings of an International Workshop at the University of Bremen, March 1991. Kiel: IPN, 310-329.

Strube, P. (1989). The notion of style in physics textbooks. Journal of Research in Science Teaching, 26, 291-299

Stinner, A. (1992). Science textbooks and science teaching: from logic to evidence. Science Education, 76, 291-299.

Sutton, C. (1989) Writing and reading science: the hidden message. In R. Millar (ed.). Doing science: Images of science in science education. London: Falmer Press, 137-159.

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WHAT HAS HAPPENED TO INTUITION IN SCIENCE EDUCATION?

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ABSTRACT

Intuition was one of the four key themes for science education that emerged from the Woods Hole Conference in 1957. Despite the considerable influence of this conference on a generation of curriculum projects the intuition theme was almost completely ignored. Recent studies of intuition, including an analysis of Nobel laureates' views of scientific intuition, are considered. This enables several conceptions of the nature and role of intuition in science to be defined, and its importance to be assessed. The assumption that it is also important in science education is examined by considering conditions in science teaching and learning that may encourage intuitive thinking in the light of current research developments that could lead to a new agenda for school science.

INTRODUCTION

Soon after the first decisions were made by the National Science Foundation (USA) in the 1950s to launch a very large campaign to renew and reform school science and mathematics, a conference was convened at Woods Hole Massachusetts. Out of this gathering of expert minds four themes were reported by Bruner (1960) in *The Process of Education* as central and fundamental to these curriculum endeavours. A great deal was heard of three of these in the years that followed. They were widely quoted as inspirational and authoritative support for much that went on as curriculum project succeeded curriculum project in more than a decade of development around the world. The theme of *Structure of the Discipline* encouraged 'big ideas' and 'key concepts'. The theme of *Readiness to Learn* took shape in terms of a spiral curriculum, and various approaches to 'age', 'stage' and 'progression'. The *Desire to Learn* encouraged activity learning and the satisfactions that the prospect of 'discovery' seemed to offer.

The fourth theme, the *Nature of Intuition*, seems to have been very largely ignored by the curriculum developers and by science education research subsequently. It came, indeed, as a surprise to me to find that it had such status when I revisited this influential book. An examination of the reports from the curriculum projects of that era and their associated materials has not revealed references to intuition as it has to the other themes. The Environmental Studies project, supported by the American Geological Institute, is possibly the one project that did endeavour to involve intuition. Only its student task cards were available. Find out how far it is from your house to school, Go outside and take a picture of power, Take a picture that is positive evidence that something natural has happened, Map something beneath the earth's surface, etc.; these may have been an attempt to include the fourth theme. It was, however, one of the least successful projects: little known among science educators and only used by a few schools for a limited period.

At this distance it is hard to explain why the intuition theme was so neglected. Perhaps it conflicted too much with the rationality and objective elegance in science that these new curricula espoused so strongly and attempted to present to students in school. Or, it may have been that the curriculum developers simply did not know how to incorporate intuition into school science or into schooling more generally.

This paper explores the claims that were made for intuition by Bruner after Woods Hole, and considers to what extent the intervening 30 years have added to our understanding of intuition in science and its potential place in school science.

INTUITION AND SCIENCE

Bruner set out to describe the nature of intuition by contrasting it with the characteristic feature of analytic thinking of proceeding a step at a time. Intuitive thinking, on the contrary, does not advance in that way. It 'tends to involve manoeuvres that seem to be based on an implicit perception of the total problem'. He further suggests that the immediate apprehension associated with intuition contrasts with the 'mediated' cognition that follows formal methods of analysis and proof.

Bruner claimed without evidence that scientists of various kinds stress the value of intuitive thinking in their respective fields. Since this assertion, the philosopher Feyerabend (1970a) has strongly supported the view that science involves irrational as well as rational processes. Newman (1975) summarised Feyerabend's thesis and contrasted his principle of 'anything goes' with those like Popper who saw science as highly rational procedures. Feyerabend (1970b) acknowledges the role in science of 'aesthetic judgements, judgements of taste and our own subjective wishes' - criteria that resonate with comments referred to below by science Nobel laureates. 'Taste not argument guides our choice of science' (Feyerabend, 1970b).

A number of accounts of the actual progression of scientific investigations, as distinct from how they have been subsequently reported in academic journals, have appeared over the last thirty years. Elliott (1988) points out that it is evident from these accounts that illogical processes occur quite frequently. Scientific research is much messier than is often supposed. Developments can be more the product of hunches and improbable connections than a series of logical and rational steps.

Marton, Fensham and Chaitlin (1992) in an ethnographic study analysed interview data from 83 Nobel laureates in physics, chemistry and medicine from 1976 - 86 who had been asked *Do you believe in scientific intuition?* Seventy two of them either declared explicitly their belief or made comments that took its existence for granted. Of the eleven who denied or expressed doubts about the existence of scientific intuition, several, however, referred to experiences that were similar to those from the seventy two. Thus, this study supports very strongly the importance of intuition in science.

Intuition was used in three distinct ways by these scientists. As an *outcome*, intuition denotes an idea, a feeling, a thought, or an answer. As an *experience* or *something that happens* intuition refers to acts or events. The third use was to *individual capabilities*. In comparison with the well known stories about Archimedes, Kekulé and Poincaré, who are all alleged to have arrived intuitively at solutions to problems, the *outcomes* of the 53 laureates who commented in this way are more often about starting points: finding, choosing a direction, a path.

> And so... as we did our work, I think, we almost felt at times that there was almost a hand guiding us. Because we would go from one step to the next, and somehow we would know which was the right way to go. And I really can't tell how we knew that, how we knew that it was necessary to move ahead. [Michael S Brown, winner of the Nobel Prize for Medicine in 1985].

Fifty of the scientists commented on the *experience*. Seventeen referred to it as subconscious processes, as a lack of a rational sense of how an idea evolved. Nine spoke of a feeling.

> ... to me it is a feeling of ... "Well, I really don't believe this result," or "This is a trivial result," and "This is an important result," and "Let us follow this path." I am not always right, but I do have feelings about what is an important observation and what is probably trivial. [Stanley Cohen, Medicine, 1986].

The feeling can be of being right or wrong but often there is an immediate intense sense of certitude.

> "... you've been thinking about something without willing to for a long time... Then all of a sudden, the problem is opened to you in a flash, and you suddenly see the answer." [Rita Levi-Montalcini, Medicine, 1986].

The feeling of being right often seems to originate from artistic and/or sensory or quasi-sensory qualities.

> There is another aspect that I would add to it, and that is, I think, taste. Taste in almost the artistic sense. Certain individuals see art in some undefinable way, can put together something which has a certain style, or a certain class to it. A certain rightness to it. [Paul Berg, Chemistry, 1980].

Thirty scientists commented on the development of intuition and only two of these referred to it as a general or partly inherited gift. Knowledge or experience of the phenomenon about which intuition occurs was what the other twenty eight saw as important.

> This apparatus ... which intuits, has to have an enormous basis of known facts at its disposal with which to play. And it plays in a very mysterious manner, because ... it sort of keeps all known facts afloat, waiting for them to fall in place, like a jigsaw puzzle. And if you press ... if you try to permutate your knowledge, nothing comes of it. You must give a sort of mysterious pressure, and then rest, and suddenly BING, ... the solution comes. [Konrad Lorenz, Medicine, 1973].

> One doesn't see with one's eyes, one sees with the whole fruit of one's previous experience. [Aron Klug, Chemistry, 1982].

From these three sources - philosophy of science, scientific realism, and an ethnographic study of scientific knowledge - considerable evidence is now available to support the contention Bruner made that intuition is important in science and it is recognised and appreciated by scientists. He went on to assume that because it is important in science it should be a significant part of school science. The extent to which such an assumption also now has support from research in science education is taken up in what follows.

FOSTERING INTUITION IN SCIENCE PEDAGOGY

Bruner explored five variables that may, he suggested, encourage intuition in learners. These were intuitive teachers, connectedness of knowledge, heuristic practice, guessing, and self-concept. Each of these are now considered with respect to the attention that subsequent research in science education has given them.

Intuition in school learners, Bruner argued, is unlikely to develop if they never see examples of it in action. He suggests that science teachers should be willing to "guess" at answers to science questions asked by the class rather than simply saying "I don't know, but I'll find out and let you know". They do know a lot of science. Hence if they are prepared to "guess", their answers will be informed by this knowledge - a quite different form of guessing from blind guessing. Such "informed guessing" followed by a critical analysis of whether the "guess" is correct or not would parallel closely the processes some of the laureates described.

> You suddenly see. It must be like this. That's intuition ... if you can't convince anybody else. This certainly happened to me in the work for which I got the Nobel prize. It took me years to get my stuff across. [Mott, Physics 1977].

There appears to have been very little research on this role for teachers despite the large amount of research in the 1960s and 1970s on questioning from teacher to class. Kam Wah (1986), found there was a great difference between teachers' behaviour as individual solvers of chemical problems and as teachers of this sort of problem. She suggested that their students would gain from observing the former modelling in action, since she had evidence that the students do try to emulate the analytic reasoning the latter model behaviour presents.

White (1988) has discussed the learning benefits that accrue from encouraging students to ask *What if?* questions in science, and the risks and rewards such metacognitive teaching poses for teachers.

There has been a great deal of research interest in connectedness in the learning of science. In the 1970s, Novak (1981) inspired by Ausubel's theory of the importance of cognitive structure in learning, began to develop tools to assess and to encourage connectedness in science learners. Pedagogies involving word association, concept mapping and Gowin's V were found to enhance science learning by making explicit the links between what students knew already and the links to be made between this existing knowledge and new knowledge.

White's (1988) book, *Learning Science*, provides many examples of the central place in constructivist teaching and learning of science that the connectedness of knowledge now has. However, I know of no research studies that have sought to capitalise on this emphasis by testing whether learners with well connected knowledge are more able to intuit answers to problems that involve the complexity of these networks of knowledge. For example, do they handle questions for which a surfeit of information is provided better than students with less connected cognitive structures?

Practice with heuristic procedures for solving problems has been well known among mathematics educators since Polya (1962) popularised them. There has been no parallel interest in them in science education and they have not featured as a variable in the reviews of problem solving in science (e.g. Tuma & Reif, 1980; Frazer, 1982). Likewise, Bruner's next variable, the encouragement of student guessing, may be what mathematics educators like Lovett and Clarke (1988) are doing through teaching estimation before analytical procedures. Official curriculum encouragement of guessing in science has not been evident, and there seems not to be yet an operationalised form of it which would enable research studies of Bruner's speculations that some sorts of guessing may be a fruitful preliminary to intelligent conjectures.

A number of the studies of gender bias have resurrected self-concept and risk-taking as variables of importance (e.g. Marsh, 1986; Linn, De Bendectis, Delucchi, Harries, & Stage, 1987; Forgasz & Leder, 1991). One reported form of this gender bias is the brashness with which boys will guess in science classes and the unwillingness of girls to participate in questioning unless they are confident of being correct (Samuel, 1983).

Bruner suggested that lack of confidence will 'freeze the student into analytic procedures'. Accordingly, if science teachers simply add encouragement of guessing to their traditional teaching repertoire, they could easily compound the gender biases. Groups like the McClintock Collective (1988) have, in recent years, provided quite new forms of pedagogy for science teachers. In these new classroom contexts it would be very interesting to see if encouragement of knowledge-based guessing would be free of gender bias and would make science studies a more positive experience for all.

OTHER CONCEPTIONS OF INTUITION

Some other recent lines of science education research can be related to intuition although with a meaning for it that does not neatly coincide with Bruner's conception of it above. Fischbein (1987) describes intuition as a type of cognition that is characterised by self-evidence and immediacy. Most of his examples are from mathematics a field of knowledge that is familiar with *axioms* as self evident knowledge, and the notion that many things such as the shortest distance between two points is a straight line, and every number has a successor, are *axiomatic*. The few examples from science are the same as some now very familiar alternative conceptions that science learners commonly hold. "A force is necessary to maintain the motion of a body". This neo-Aristotelian view has been widely reported and in very diverse cultural settings (e.g. Viennot, 1979; Clement, 1982; Watts, 1983; Gunstone, 1987;

Boeha, 1988). Some of Fischbein's characteristics for intuition are also very familiar in the conceptions research literature. For example, "intuitions are stable acquisitions, resistant to alternative interpretations".

Another is the coercive effect that intuitions exert on an individual's reasoning strategies. The combination of self-evidence and this coerciveness are very interesting to consider in relation to the pedagogical strategy of cognitive conflict for bringing about conceptual change (Nussbaum & Novick, 1982). If a number of the common alternative conceptions in science repeatedly reported during the last decade are in fact self-evident axioms, then proof is an irrelevant notion. Any form of cognitive conflict is likely to be unsuccessful in bringing about change. This is consistent with the sober findings now emerging from a number of research studies that have used this pedagogy (Scott, 1988).

Fischbein's view of these intuitions (conceptions) as self-evident may also help to resolve the bewildering transcultural occurrence of some alternative conceptions. Otherwise, if as has often been assumed, they are derived from cultural experiences and common-sense extra-school knowledge, why does Boeha find the same conceptions in physics students in New Guinea as Viennot in France or Clement in the USA?

Bruner expressed a concern that the system of rewards and punishments in schools could inhibit intuitive thinking by its emphasis on the correct answer. Almost 30 years later one of the Nobel laureates in 1986, echoed this very same concern but, in doing so, made reference to an aspect of the scientific enterprise that has rarely been recognised or advocated by curriculum developers and teachers. These are the situations in science where there is a lack of understanding, where there are no answers and certainly no right one.

> I'm afraid that in our educational system, we do not have means whereby we really foster, as much as we could or should, this intuition or whatever. Because, for example, in our science courses, the students typically have the impression - certainly in the elementary or beginning courses - that it's a question of mastering a body of knowledge that's all been developed by their ancestors. And particularly, the problem that's serious there, is that they get the impression that what really matters is being right or wrong - in science above all ... And I like to stress to my students that they're very much like the research scientists: that we don't know how to get the right answer; we're working in areas where we don't know what we're doing. The difference is we are happy when we don't understand something. We think there's a chance we might learn something new and special. We have this confidence born from some experience - and maybe a reckless turn of mind or whatever, whereas a beginning student runs a risk of being intimidated by it. So I think any way we can encourage our students to see that, in science, it's really, in a way, not so important whether you're right or wrong at this particular moment. Because, as I said earlier, the truth is going to wait for you. And you can zigzag back and forth on your way up the mountain. And often, the key thing, if you're going to be wrong, is to be wrong in an interesting way - because you tried some excursion in thought

> that took you over somewhere and gave you a new perspective. That's the kind of thing to try to emphasize. [Herschbach, Chemistry 1986].

The idea that school science should be more prepared "to wait" has, however, been taken up by several researchers in response to the continued failure of students to achieve what had hitherto been regarded as rather elementary ideas despite some of the best constructivist teaching we know how to implement. For example, Millar (1990) argued for a much more oblique approach to the teaching of kinetic theory that builds from students' naive questions about matter, and their accumulation of examples and specific instances.

Appelman, Colton, Flexer & Hawkins (1981) referred to the alternative conceptions that learners hold about science as *critical barriers*, and research studies soon suggested these barriers to conceptual change would be difficult to overcome. In such a sobering situation I (Fensham, 1982) suggested science educators should in some topics be content with the modest goal of making students aware that scientists often find it useful to hold different conceptions from everyday ones many students hold. In other words, the "wait" for the scientists' truths to be taken on board personally by school students may have to be until after they have made the decision to study to become a professional scientist.

CONCLUSION

In comparison with 1957 when the Woods Hole group decided that intuition was important for the reform of science curriculum, more is now known about the nature and place of scientific intuition in research.

Conceptual understandings of common natural phenomena, that differ from the current scientific view, are widely held among learners of all ages. The thinking associated with these has characteristics such as immediacy, intrinsic certainty, and coerciveness that are also associated with scientific intuition. When these alternative conceptions also have the property of self-evidence, Fischbein has called them intuition. These understandings have been the subject of intensive research and their significance is now firmly established as quite integral to learning science. Furthermore a number of the pedagogies for science that have emerged from these research studies provide conditions for learning that were also suggested from Woods Hole.

There is, however, little evidence that intuitive thinking as such is any more encouraged in today's science classrooms and curricula than it was in the reforms of the 1960s. Science teachers and the supporting curriculum materials generally take a step-by-step approach to science topics. Probably only a few science teachers model intuition to their students or could recognise intuition in their students if and when they think in that way. So far research studies that could assist teachers in these matters seem not to have begun.

The Nobel laureates spoke about intuition in situations where they were overloaded with information on a topic or problem. This is hardly a situation that has an easy counterpart in school science. Rather students are pushed to use or asked to assimilate concepts well before they have encountered even a small fraction of the phenomena or empirical findings that in science justified the invention of these concepts. These are hardly conditions that encourage intuition.

Driver (1975), unaware of the very significant role that technology education would take on in 1990s schooling, pointed out that technological problems involve a surfeit of possibly relevant information and optimal answers rather than one "right" one. In this sense she suggested that they may provide a better vehicle for intuitive thinking in science than purely scientific ones. The currently emerging science curricula do seem still to stop short of this type of problem solving, whereas those emerging for technology with their emphasis on design may positively encourage such intuitive thinking.

REFERENCES

Appelman, M., Colton R., Flexer, A., & Hawkins, D. (1981). A report of research on critical barriers to learning and understanding of elementary science. Boulder CO: Mountain View Center, University Museum, University of Colorado.

Boeha, B. (1988). Some students' beliefs in mechanics : a Third World viewpoint. Research in Science Education, 18, 298 - 309.

Bruner, J.S. (1960). The process of education. Cambridge, MA.: Harvard University Press.

Clement, J. (1982). Students' preconceptions in introductory mechanics. American Journal of Physics, 50(1), 66 - 71.

Driver, R. (1975). The name of the game. School Science Review, 56, 800 - 805.

Elliott, B. (1988). Technology and social process. Edinburgh: Edinburgh University Press.

Fensham, P.J. (1982). A research base for new objectives of science teaching. Science Education, 67, 3 - 12.

Fensham, P.J. (1990). What will science education do about technology? Australian Science Teachers Journal, 36(3), 8 - 21.

Feyerabend, P.K. (1970a). Consolations for the specialist. In I. Lakatos & A. Musgrave (eds.) Criticism and the growth of knowledge, Cambridge: University Press.

Feyerabend, P.K. (1970b). Against method. Minnesota Studies in the Philosophy of Science, 4 17 - 30.

Fischbein, E. (1987). Intuition in science and mathematics : An educational approach. Dordrecht: Reidel.

Forgasz, H.J. & Leder, G.C. (1991). To guess or not to guess : a question of risk, Mathematics Competition, 4(2), 58 - 69.

Frazer, M.J. (1982). Solving chemical problems. [Nyholm Lecture] Chemical Society Reviews 11(2), 171 - 190.

Gunstone, R.F. (1987). Student understanding in mechanics: a large population survey American Journal of Physics, 55 691 - 96.

Kam Wah Lee (1986). Problem solving in electrochemistry : variables, strategies and teaching and learning. Ph.D. thesis, Clayton, Victoria: Monash University.

Linn, M.C., De Bendectis, T., Delucchi, K., Harries, A., & Stage, E. (1987). Gender differences in national assessment of educational progress science items : What does "I don't know" mean? Journal of Research in Science Teaching, 24, 267 - 78.

Lovett, C. & Clarke, D. (1988). MCTP Activity Bank, Vol 1, Canberra: Curriculum Development Centre.

McClintock Collective (1988). Getting into gear : gender inclusive strategies in science, Canberra: Curriculum Development Centre.

Marsh, H.W. (1986). Verbal and math self concepts : an internal external frame of reference model. American Educational Research Journal, 12, 129 - 49.

Marton, F., Fensham, P.J., & Chaitlin, S. (1993). A Nobel's eye view of scientific intuition, International Journal of Science Education (accepted for publication).

Millar, R. (1990). Making sense : what use are particle ideas to children? In P.L. Lijnse, P. Licht, W. de Vos & A.J. Waarlo, (eds). Relating macroscopic phenomena to microscopic particles. Proceedings of a seminar, Utrecht: Centre for Science and Mathematics Education, University of Utrecht, 283 - 293.

Newman, B. (1975). Scientific methodology : a Feyerabendian view. Research in Science Education, 5, 99 - 111.

Novak, J.D. (1981). Effective science instruction : the achievement of shared meaning. Australian Science Teachers Journal, 27(1), 5 - 13.

Nussbaum, J. & Novick, S. (1982). Alternative frameworks, conceptual conflict and accommodation : Toward a principled teaching strategy. Instructional Science, (Vol 11). 183 - 200.

Polya, G. (1962). Mathematical discovery ; on understanding, learning and teaching problem solving (Vol I). New York: John Wiley and Sons.

Samuel, J. (1983). Science. In J. Whyld (ed) Sexism in the secondary curriculum, London: Harper and Row.

Scott, P. (1988). The process of conceptual change in science: a case study of the development of a secondary pupil's ideas relating to matter. Proceedings of Second International Seminar Misconceptions and Educational Strategies in Science and Mathematics (Vol II) 404 - 419, Ithaca, N.Y. Cornell University.

Tuma, D.T. & Reif, F. (eds) (1980). Problem solving in physics : Issues in teaching and research. Hillsdale, N.J.: Lawrence Erbaum.

Viennot, L. (1979). Spontaneous reasoning in elementary dynamics. European Journal of Science Education, 1(2), 205 - 24.

Watts, D.M. (1983). A study of school children's alternative frameworks of the concept of force. European Journal of Science Education, 5(2), 217 - 230.

White, R.T. (1988). Learning science. Oxford: Blackwell.

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RECONSTRUCTING THE INTERACTIVE SCIENCE PEDAGOGY: EXPERIENCES OF BEGINNING TEACHERS IMPLEMENTING THE INTERACTIVE SCIENCE PEDAGOGY.

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ABSTRACT

Six beginning primary school teachers pioneering the Interactive Teaching approach to science were studied in their first year of teaching. Interviews with the beginning teachers revealed that they faced several obstacles to the implementation of the interactive teaching of science. These included lack of collegial support, lack of feedback on their teaching, difficulty assessing the learning of their pupils, and the differences between the culture of learning of the alternative science pedagogy and that of their pupils. By the end of the year, teachers had reconstructed the alternative science pedagogy in ways that reduced these difficulties. The interviews also provided evidence that ongoing support by teachers and teacher-educators versed in the alternative pedagogy can make beginning teacher's implementation of the Interactive Teaching of science less difficult.

INTRODUCTION

Beginning teachers often experience a "reality shock" when they begin their teaching careers (Wubbels, Creton, Hooymayers, & Holvast, 1982; Cooke & Pang, 1990; Marso & Pigge, 1987). The initial experiences of the reality of the classroom may make young teachers irritable and depressive and they may doubt whether they will ever become good teachers (Muller-Fohrbrohdt, 1973). There may also be a discarding of innovative attitudes by beginning teachers (Olgers & Riesenkamp, 1979). Discipline may emerge as the major concern of beginning teachers (Veenman, 1984; Cooke & Pang, 1990).

The origins of "reality shock" may lie in the difficulty that beginning teachers have in constructing a satisfactory teaching role for themselves. The expectations of colleagues and pupils may run contrary to the beginning teacher's own wishes. Their expectations reflect the institutional nature of schooling such as the hierarchy of power, the gender regime, the workplace conditions such as class size, timetabling, availability of resources, the difficulties of relationships with learners. Beginning teachers experience their own inability to turn their ideals and wishes into concrete behaviour (Wubbels et al., 1982).
In the first year of teaching the beginning teacher may develop from initial concerns with self-preservation, to concerns about tasks, and later to concerns about the impact of those tasks on the learner (c.f. Fuller, 1969; Adams, 1982). The teacher may also progress from being merely an implementer of a pedagogy, to feeling a sense of control over the pedagogy (c.f. Schon, 1987; Baird, Mitchell & Northfield, 1987). Some beginning teachers will develop as reflective practitioners (Schon, 1987), others may become locked into being a replicate of the teachers that they had been taught by (c.f. Knowles, 1987).

What the outcome of the first year of teaching is in terms of a teacher's development, may depend upon a number of factors. Wubbels et al. (1982) suggest the main elements to be personality of the teacher, (e.g. their willingness to try out new ideas), their ideals influenced very much by their past experiences in their own education (e.g. acting democratically and taking personal responsibility), and thirdly the school environment which includes the different expectations of other teachers, pupils, and principal.

The research reported here studied the experiences of beginning teachers in their first year of implementing an alternative science pedagogy. The research looked at the difficulties, role strain and reality shock, that the beginning teachers experienced as a consequence of their teaching science quite differently from other teachers in their schools. Changes in the beginning teachers' ideas and science pedagogy were examined in relation to their implicit theories, past experiences, and their difficulties and supports at school.

The research took the form of a one year longitudinal study exploring the experiences of beginning primary school teachers who were enthusiastic and committed to the I.T. approach. These teachers were interviewed at the end of term 1 of their first year of teaching at school. Three teachers were then followed up for the rest of the year through observations of their science lessons and further interviews.

The Alternative Pedagogy

The interactive teaching (I.T.) approach was developed by the Learning in Science Project (LISP) team at the University of Waikato. The pedagogy of the I.T. approach is explained in depth in the book Making Sense of Our World by Biddulph and Osborne (1984). It involves five phases: preparation, exploration, children's questions, investigations and reflection. The key feature of the approach is children asking questions about the science topic and their involvement in investigations to seek answers to their questions. The progress of their learning can be studied from their before statements or views (children's ideas at the beginning of a science unit) and their after statements or views (children's ideas at the reflection stage of the unit). By the late 1980's the I.T. approach was being taught to training primary school teachers in a number of Colleges of Education in New Zealand. The research reported here is the first in-depth qualitative research into the experiences of beginning teachers implementing the approach.

METHOD

The transcripts reported in this paper are taken from interviews with six beginning teachers who were committed to implementing the I.T. approach for teaching science. The six comprised one male and five females in their early twenties, two of whom were of Maori descent and four of European descent. They were selected upon consultation with their Teachers College lecturers. All were perceived by their lecturers as committed to the Interactive Teaching approach, and were willing to take part in the research.

Six beginning teachers were interviewed after completing Term 1 in their first year of teaching. Four were interviewed in their classrooms and two in their homes. The interviews lasted between two to three hours and all were audiotaped. They were transcribed and the transcripts returned to the teachers for clarification. Three of the six teachers were followed through for the rest of the year with classroom observations and interviews.

In the interviews at the end of term 1, teachers were invited to reflect on their experiences as beginning teachers implementing the I.T. approach in science. The researcher had some broad areas where reflection could be focused if necessary and some guiding questions for each area of interest.

The five broad areas and their guiding questions were:

- experiences as a beginning teacher in Term I.
- views about learning/teaching of science.
- views about their school environment.
- own schooling background particularly of science experiences.
- experiences at Teachers College

In the interviews at the end of their first year of teaching, the three selected teachers were invited to reflect freely on any issues from the past year. The main exploration was in the area of changes with respect to behaviour, attitudes and views of the beginning teacher in the first year of teaching and in particular, teaching of science.

RESULTS

The interviews with the beginning teachers revealed that they had experienced a number of difficulties in their first term of teaching. Some of these difficulties were common to all beginning teachers; others were associated with the pioneering of an alternative pedagogy. In the account below we give examples of the difficulties which arose from implementing an alternative science pedagogy, of the supports that teachers found valuable, and of some of the changes in approach of the three beginning teachers who were followed for the year.

Difficulties in Implementing I.T.

All six beginning teachers experienced difficulties in their first term in school. These difficulties hindered teachers in their implementation of I.T., and were responded to in different ways by them. Seven types of difficulty that impacted on the implementation of I.T. were identified. These difficulties are listed below along with comments of the teachers which illustrate the nature of these difficulties.

* Lack of support from colleagues:

> I discussed with him (tutor teacher) the approach ... and got my friends to send a video down on a unit done on "Trees". I wanted him to look at the video because I wanted to try the approach. He wasn't impressed with it ... He didn't think much of the approach.
> (Teacher C, Interview I)

* Lack of feedback from others knowledgeable in the I.T. approach:

> There was no real in-class support. There was no observing a lesson and talking to me after class saying "This is the feedback I want to give you." ... I felt 'are they actually learning? Have they actually done something or am I just sort of entertaining, just keeping them busy?', because I wasn't getting any feedback.
> (Teacher B, Interview II)

* Difficulties in validly assessing the learning happening in their classrooms:

> The biggest worry is that you can't write down what the children had learnt. They still expected evaluations. I have to test these kids. I tried to test them and I was shocked at what they hadn't learnt ...

> Necessity to give a test is hard. It's so hard to check the interactive approach. I should really have a checklist for evaluation related to the interactive approach but I don't have time to mark it off. I'm not really evaluating the children individually enough. But I find evaluation very hard this year, because I just have no time to begin with. I didn't require them to do any writing, there was hardly any writing, so I wouldn't know how to test. I'm sure they learnt
> (Teacher A, Interview I)

* Concerns about covering the content that is expected of their pupils in future years:

> I think, 'Oh I am not really teaching them anything.' Sometimes I think, 'Gosh, what are they supposed to know before they get to intermediate?' There's always this ...'Maybe the parents are thinking that I'm not teaching them enough.'
> (Teacher C, Interview II)

* The lack of familiarity of children with their roles as learners under the interactive approach:

> I think that basically these children have been spoon-fed a lot. They have been taken too much by the book. Consequently they don't know how to ask questions for themselves and that makes it hard ... It's different from what they had before."
> (Teacher F, Interview I)

* Lack of ideas in the planning and organisation of interactive science lessons:

> "They would ask questions like 'why is the yolk round?' which is a really neat question (I was rapt about that) but how to find the answer to why the yolk is round - it was just beyond me.... Like we do the beginning where they ask a lot of questions and they experience them. But then there is that part where they are supposed to experiment and move along with their questions, that's the bit missing."
> (Teacher D, Interview I)

* Having the time and ideas to develop resources:

> It gets really hard when you see all these other teachers sitting around at lunchtime and going home at three o'clock, and teaching is a breeze to them. I'm tearing my hair out, running around all day. I'm here till six o'clock at night and I go home to do some more work and my day is not organised even at that. I think, 'What the hell am I doing, it'll be much easier to do what everybody else is ...find out what they are doing and do what they are doing.' So that's the greatest pressure.
> (Teacher B, Interview I)

Supports for continuing with I.T.

Faced with the difficulties listed above, certain types of support were critical in the beginning teachers decision to continue with the alternative pedagogy. Five types of support were the main reasons for continuing with interactive teaching:

* Support from peers that allowed the teacher to view positively their efforts as a beginning teacher:

> At the beginning of the year, it [group support] was really important because we're all just about ready to quit, we're all struggling and it was so nice to know that we weren't the only ones...
>
> To go back home and realise that other people were in worse situations or were having the same sort of problems was really important. But as the year went on, the group petered out so that was when everybody was feeling they've got more confidence.
> (Teacher A, Interview II)

* Encouragement from other teaching professionals for the beginning teacher's efforts to implement Interactive Teaching:

> The staff are really good ... they give me the positive encouragement that I need ... Having a staff like this really helps towards being successful in the classroom.
>
> I showed it [a child's work] to another teacher and she went 'Wow! how did you get him to do it?' ...My tutor teacher came in and looked at my learning centres and she said that she was gaining so many ideas for her classroom. In a way I guess that's good too.
> (Teacher F, Interview I)

* Assistance with resources for Interactive Teaching:

> ... got up to college and got ideas off M. and J. [Teachers College lecturers]. I wouldn't have done electricity if college hadn't lent me the equipment.
>
> So long as I have the college here and the support here from the college then I'll use it [I.T.].
> (Teacher A, Interview I)

* Encouragement from the response of learners to the science lessons:

> One of the main things that I enjoyed... One of the things that really impressed me was ... some of the children who were slow to work, when they read out their after statements, they could see how much they had learnt and just to see the sparkle in their eyes was enough for me. Some of them may not have learnt a lot but I can say all of them learnt something about mammals. Even now I can pull out questions and they can answer.
> (Teacher C, Interview I)

* Their belief that using I.T. they could teach science in spite of coming from a limited science background.

> Even at Teachers College, I was scared about doing science curriculum...We did electricity...it was neat because I didn't have to know more than them. I thought this was a really neat idea. I'm not expected to be God and they are not expected

> to learn masses... It's good because it takes a lot of stress off me because I don't have to pretend I'm something I'm not.
> (Teacher D, Interview I)

Changes in the beginning teachers' science teaching

The three teachers who were followed through all their first year of teaching evidenced changes in the way that they taught science. The changes evinced by the teachers included more content and structure in the topics they taught, more emphasis placed on the need for guidance by the teacher, and increased consideration of the need to prepare pupils for future years of schooling.

> At the beginning, I thought that I had to have before statements and questions, and that I couldn't put anything structured in at all because that wasn't the interactive approach. But now I don't, now I do what suits me in the class. (Teacher A, Interview II)

> I think it's good [referring to a mix of methods], that's why I haven't used it [I.T.] fully. Now and again I might have somebody say, "Gee, you know at intermediate, a lot of children didn't know this." You sort of manipulate a couple of things. That's not the interactive approach but I think that if the children need to survive over there they better know this. But I try to manipulate it so that they feel that they were not forced to learn it. (Teacher C, Interview II)

> I have come to realise the extent which teacher direction is needed. The interactive approach won't work on itself or won't work with just the kids going for it because they need direction and guidance and focus. They need to be shown how to go, or when they are going, be given ideas how to get there. (Teacher B, Interview II)

By the end of the year, all three teachers had moved from a phase of their teaching life in which the I.T. pedagogy dictated their science teaching goals, to a phase in which they set their own goals in teaching science. At the end of the year, elements of I.T. were still utilised in their teaching, but they had developed their own approaches to teaching science. In spite of the changes, all three teachers remained committed to the child-centred education philosophy underlying I.T.

> Even in my more structured science there's still a lot of interactive approach in there, still a lot of questioning ... In every topic I'll always stick to that because I think that's neat, something that the children don't get to do much, ask questions and find out the answers without being told them, and it's activity based ... I choose bits of the interactive approach. (Teacher A, Interview II)

> I still believe in the importance of the child as central. There needs to be a lot of teacher input though, teacher involvement in that, but the child is central and control their learning. (Teacher B, Interview II)

> I don't think I've used it [I.T.] approach fully. But I think that I am improving all the time and getting towards that goal, using the approach fully. I have to an extent used it but not fully. Last year I just touched upon a lot of things, whereas this year I really want to develop in the interactive approach, further than what

> I've done. I feel I'll get there. I'm confident I'm going to use it, that's better than last year. (Teacher C, Interview II)

DISCUSSION

All the beginning teachers interviewed had made efforts towards teaching science using the Interactive Teaching approach which they had learnt while at Teachers College. Implementing the I.T. approach in their first year of teaching had not been easy for any of them. By the end of their first year, these beginning teachers were aware of a number of difficulties constraining their implementation of I.T., and had modified the Interactive Teaching approach that they had learnt at Teachers College. The changes these teachers made in their approach to teaching science can be interpreted as their adaptations to the difficulties.

As well as the usual difficulties of beginning teachers these teachers had other difficulties associated with pioneering an alternative science pedagogy in the school, and they grappled with these difficulties in various ways. For example, Teacher A overcame lack of feedback about her teaching by comparing her experiences with those of other beginning teachers in a social group; Teacher B relied on the feedback of a progressive Deputy Principal. The difficulty of isolation was overcome by Teacher C through initially teaching according to the advice of her tutor teacher; Teacher A on the other hand, began teaching interactively, but without telling her principal. The teachers' response to the assessment difficulty was to ensure that some content was learnt in their science sessions, and in those schools which did not dictate the assessment scheme, the beginning teachers utilised qualitative assessment approaches. The issues of time and resources needed to teach interactively, were responded to by Teacher B by putting in long hours to develop interactive science units; Teacher A reduced preparation time through contact with the Teachers College for resources.

It appears that in the first year of teaching these beginning teachers were actively reconstructing their roles as science teachers. Three aspects of their reconstruction are apparent. Firstly, the beginning teachers moved towards more conventional practices in science teaching. Secondly, the beginning teachers felt ownership and control of their modified approach. Both of these trends are in line with the findings of previous research into beginning teachers (e.g. Olgers & Reisenkamp, 1979; Baird et al., 1987). A third aspect of their reconstruction of teaching was that there appears to have been no fundamental shift in the ideas guiding the development of their teaching practice. In reconstructing their role as innovative teachers, these teachers retained their commitment to the ideas taught when they attended Teachers College. This outcome differs from the findings of previous research (c.f. Munro, 1988). It is possible that the reason for their retention of their ideas about science teaching is that their experience of science as an enjoyable, open-ended activity at Teachers College had a profound effect on their thinking about science and science teaching. This suggestion is supported by the evidence of other sections of the transcripts not included in this paper (c.f. Fernandez, 1991).

In terms of professional development as teachers, their pioneering an alternative pedagogy had both positive and negative impacts. Because they were aware that they were pioneering an alternative way of teaching, they were critical of established practices to a level beyond that of most beginning teachers. Not accepting established practices meant that they took responsibility for the development of innovative lessons, rather than relying on existing resources. They developed skills in curriculum development and in terms of Interactive Teaching all had made big steps towards becoming competent practitioners.

On the negative side, it appears that some of these beginning teachers were plunged into taking so much responsibility for learning outcomes that they never felt sure that their efforts were good enough. Other beginning teachers have to grapple more with the concern of whether they are behaving like the experienced teachers, than the concern of what the impact of the teacher's role is on learners. Not so for these beginning teachers. In a sense they bypassed the survival stage of teacher development (c.f. Fuller, 1969; Adams, 1982), and went straight into grappling with concerns about the effects of their teaching model on their pupils. The impact on the beginning teachers of this added issue is exemplified in the following comment of one of the teachers:

> I felt like I was just suspended in mid-air, there's nothing supporting me or holding me up; I sort of blundered along doing what I thought was right. I was hoping, crossing my fingers that it was the right thing. That is honestly how I felt all the way through. (Teacher B, Interview II)

In terms of science curriculum change, the significance of this research is that it demonstrates the need for ongoing involvement in school by those promoting curriculum change. Just training teachers in an alternative pedagogy and then sending them into schools will not necessarily hasten curriculum change. The difficulties of the beginning teachers show that there are institutional pressures within the school for beginning teachers to abandon alternative ways of teaching science (c.f. Martinez, 1987). Because beginning teachers have considerable need for support and feedback from their teaching colleagues, they are vulnerable to these pressures. Thus, while an alternative science pedagogy can be pioneered by beginning teachers, critical to the ongoing commitment of these teachers to the alternative pedagogy is support by others informed by the pedagogy. Teacher educators have a crucial role to play in developing ongoing programmes to support teachers pioneering innovative ways of science teaching.

REFERENCES

Baird, J.R., Mitchell, I.J. & Northfield, J.R. (1987). Teachers as researchers: the rationale; the reality. Research in Science Education, 17, 124-138.

Biddulph, F., & Osborne, R. (1984). Making sense of our world: an interactive teaching approach. University of Waikato, Hamilton, N.Z: SERU.

Britzman, D.P. (1986). Cultural myths in the making of a teacher: biography and social structure in teacher education. Harvard Educational Review, 56, 4,.

Butler, J. & Beasley, W. (1988). Teacher classroom management styles with beginning high school students. Research in Science Education, 18, 177-185

Clarke, C.M.(1988). Asking the right questions about teacher preparation: contributions of research on teacher thinking. Education Researcher, 17, 2, 5-12.

Cooke, B.L. & Pang, K.C. (1990). Entry characteristics of trained and untrained beginning teachers. Paper presented at the world assemby of the International Council on Education for Teaching, Singapore.

Driver, R. (1983). The pupil as scientist? Milton Keynes: Open University Press.

Eddy, E.M. (1969). Becoming a teacher. Columbia University : Teachers College Press.

Fernandez, T.F. (1991) Implementing an alternative primary school science pedagogy: Experiences of beginning teachers. Unpublished Masters Thesis, Hamilton: University of Waikato.

Fuller, F. (1969). Concerns of teachers: A developmental conceptualisation. American Educational Research Journal, 6 (2), 207-226.

Knowles, J.G. (1987) What student teachers' biographies tell us: implications for preservice education. Paper presented at the first joint conference of the AARE and NZARE. University of Canterbury, Christchurch, New Zealand.

Lortie, D. (1975). Schoolteacher. Chicago: University of Chicago Press.

Marso, R.N. & Pigge, F.L. (1987). Differences between self-perceived job expectations and job realities of beginning teachers. Journal of Teacher Education, 38 (6), 53-56.

Martinez, K. (1987). Encounters of the first kind. Paper presented at the first joint conference of the AARE and NZARE. University of Canterbury, Christchurch, New Zealand.

Muller-Fohrbrohdt, G. (1973). Wie sind Lehrer wirklich? Stuttgart, Klett (in Dutch), cited in Wubbels et al.,1982.

Munro, R. (1988) Personal biography in the shaping of teachers. Paper presented at the Mathematics Education Conference. Christchurch, N.Z.

Olgers, A.J. & Reisenkamp, J. (1979) De onderwijskundige voorbereiding van aan-staande leraren. Haren: RION, cited in Wubbels et al., 1982.

Osborne, R.J. & Freyberg, P. (1985) Learning in science: the implications of children's science. Auckland: Heinemann.

Pope, M. & Gilbert, J. (1983). Personal experience and the construction of knowledge in science. Science Education, 67 (2), 193-203.

Schon, D. (1987). Educating the reflective practitioner: toward a new design for teaching and learning in the professions. San Francisco: Jossey-Bass.

Wittrock, M.C. (1974). Learning as a generative process. Educational Psychologist, 11, 87-95.

Wubbels, T., Creton, H., Hooymayers, H. & Holvast, A. (1982). Training teachers to cope with the 'reality shock'. Studies in Science Education, 9, 147-160.

Veenman, S. (1984) Perceived problems of beginning teachers. Review of Educational Research, 54 (2), 143-178.

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INTRODUCING TECHNOLOGY EDUCATION TO YOUNG CHILDREN: A DESIGN, MAKE AND APPRAISE APPROACH

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ABSTRACT

The National Statement on Technology Education will soon be released in Australia. The statement advocates a design, make and appraise approach to technology education. The document includes Year One children and provides exemplars of curriculum activities for early childhood children. Although much curriculum development in technology education for primary and early childhood has taken place in the UK, little research has been conducted within the early childhood area in Australia. This paper describes a study which sought to investigate how the design, make and appraise approach could be implemented within early childhood using existing materials, procedures and teaching programmes. In particular, the pre-school programme was considered to see if the approach was suitable for young children, and if girls could be encouraged into this newly defined area of study.

INTRODUCTION

Science and technology have recently been placed on the national agenda (Fensham, 1990). The National Statement on Technology Education, currently being developed, focuses on a design, make and appraise approach to education. The accompanying rationale speculates that such an emphasis will yield citizens who will be problem solvers and who will be able to think divergently and contribute to the notion of a clever country (Australian Education Council, 1992).

Very little research is available on how to introduce this newly defined area of study into early childhood education (Browne, 1991). Given the concerns in the literature about the masculine image of science (Kelly, 1987) and the associated difficulties of involving girls and women in science (Harding, 1983), it is imperative that this does not happen with the introduction of technology education. Research in the UK into technology education in early childhood has shown the difficulties of access to technology resources by girls (Beat, 1991) and the need for careful teacher involvement during girls' and boys' construction work so that it is inclusive of girls' interests, skills and learning styles (Browne, 1991).

This paper discusses how Technology Education can be introduced to young children so that it is inclusive of girls' interests and needs in ways consistent with the physical structure and philosophy of early childhood education. The curriculum content used to implement this approach focuses upon the design and construction of a simple (model) house.

THE APPROACH

The design, make and appraise approach to technology education is somewhat problematic in early childhood. With children below five years of age, it is difficult to utilize the design aspect of the approach. In general, children's representational skills are rudimentary; more specifically, in the context of house design, the bird's eye perspective (plan view) may not have been considered before by such young children. Consequently, a carefully sequenced and cognitively oriented approach to technology education must be planned for in early childhood. Vygotsky's (1978) notion of socially constructed learning, and in particular Bruner's (1987) scaffolding metaphor have been drawn upon as first, the paradigm being adopted, and second, the particular learning strategy used by the teacher to introduce technology education. The teaching sequence was developed with the premise that the technology experience should be introduced for a social purpose and should continually focus on extending children's development so as to maximize potential learning (zone of proximal development) through the adult and child working together on tasks deemed to be too difficult for the child working alone. Vygotsky's socially constructed learning orientation is also supportive of research which emphasizes the importance of a social perspective for encouraging and maintaining girls' involvement in early childhood technology education (Beat, 1991).

Bruner's scaffolding metaphor has refined Vygotsky's orientation so that it is achievable in the classroom/pre-school. Teacher modelling and the gradual handing over of task completion to children was an important element of the teaching process in this study.

The simple yet unfamiliar approach advocated by the National Statement on Technology (design, make and appraise) requires early childhood teachers to take an active role in modelling and scaffolding each stage. First, it is important to orient children's attention to the bird's eye view (plan view) when drawing and constructing. This can be done through the teacher modelling this perspective to children (details outlined under teaching sequence). The second area which needs to be modelled to children is drawing their design before constructing. Once again this focus is not familiar to children and needs to be carefully introduced to young children. The teaching sequence below outlines how this orientation was introduced. The appraisal phase of the approach was deemed too problematic for the young learners and was not considered in this study. Only the design and make phase were detailed.

The teaching sequence

It was seen as desirable to dedicate at least one group time per session (preferably the main morning one) to technology education when it was first introduced to the children. This was important because the design, make and appraise approach was not familiar to children and needed to be modelled to them. After group time it was imperative for the teacher to locate herself in the block area working with interested children (whilst still maintaining overall supervision). UK research has shown this to be a useful strategy for encouraging and maintaining girls' involvement (Beat, 1991).

The teaching sequence occurred over two weeks in order to achieve the depth required for introducing the new approach. Children were introduced to the technological approach through a meaningful and familiar context: story telling. The Three Little Pigs story was told using puppets, blocks (for the brick house), straw and stick pig homes. Follow-up activities in the block corner included the children building the pigs' homes, their own homes and other house constructions.

Using adjuncts (door frames and doors, windows, people and furniture) and having the teacher work together with children ensured that the girls continued to work in the block area, and that the building continued to be related to house construction. At all times the children were encouraged to draw a plan. Initially children drew the plan view only after house construction, later the children drew it before construction. The teacher continually modelled how to draw a plan view through helping children see this perspective (as shown below in Transcript One) and through drawing her own plan view and then constructing the house. Later, children's plan views were shown at group time, where the teacher discussed the use of space and the bird's eye perspective taken by the children.

Transcript One:
T: This house is special because I can see right down inside that house
Charlie: 'Cause you didn't have a roof on that house.
T: It hasn't got a roof. I didn't put a roof on for a special reason. I wanted you to have a look inside the house....
T: I'm going to pretend that I'm a bird. What do birds do Jena?
Ben: [Flapping wings].
Jena: Fly.
T: They fly, don't they? If a bird flew over this house and had a look down inside, I wonder what it could see. I'm going to choose some special people who are sitting down to be birds. Andrew, would you like to be a bird and fly over the pig's house and tell me what you can see in there? Tell me what rooms you can see.
Andrew: Everything.
T: What's everything? What sort of rooms are in there?
A: Bedroom, dining room, bedroom.
T: Thank you. Eloise, you're sitting beautifully, would you like to be a bird flying over the house?...What can you see Eloise? How many...
E: Some beds.
T: Some beds.
E: Kitchen.
T: And a kitchen!
E: And a dining room.

THE STUDY

This study sought to find out if children as young as three would be able to adopt the design, make and appraise techniques advocated by the National Statement on Technology Education. An early childhood technology education programme was developed (as discussed above) and implemented over a two week period (7 days in total) in the pre-school room of a Creche. Most participants were aged 3½ and 4; some were 5 years old. The attendance over the two weeks was variable, as is typical in part time child care centres. On most days the group size ranged from 20 to 25 children, with a core of 8 regular attenders.

All whole group sessions which focused on technology education were video-taped. All free-choice sessions which immediately followed group time were also video taped and all key interactions between the teacher and the children were audio-taped. The video-taping of free-choice time was more problematic. It was impossible to record all aspects of each child's house construction, since there were at least six children concurrently involved in building. A total of 12 hours of audio tape and four hours of video data were collected. All discourse from the video and audio tapes was transcribed.

All house plans drawn by the children over the two week period (7 days) were collected and analyzed in terms of the representational skills, and how the children used them for building. Samples of the children's work are presented in this paper. When the children's designs were contrasted with their construction work, a more complex picture of the whole process emerges.

FINDINGS

It was found that initially children had limited representational skills and consequently were unable to represent the design of their building (let alone design it before construction). The plan view perspective was something that the children had never represented before. Helping children to consider the design aspect before construction was also particularly difficult, since children were completely unfamiliar with such an approach to constructing in the Creche. These two findings are considered in this section.

The design component of technology education

In the following illustrations it is evident that children were able to define boundaries (a complex spatial relations concept) and were able to draw from a variety of perspectives, including a plan view. The complexity of the plan view developed over the two week period for most children. This is particularly evident in Jena's sequence of two plan views drawn on subsequent times throughout the data collection phase.

In Fig. 1, Jena has drawn a plan view of her own house. She labelled each part of her plan view as she drew it. Some of the lines throughout the design (Reference Point One) indicated the pathway from the door to the defined space (bedroom). Although Jena defined the space, she had not created a boundary for the house or for each of the rooms.

In Fig. 2, Jena's plan view displays more form and sophistication. She has drawn a boundary to her house and has created defined spaces within the main boundary to represent rooms. A clear progression of development is visible from Fig. 1 to Fig. 2. Whilst development in children's representational skills occurred throughout the two week period, the children's ability to represent the plan view was variable among the whole group. Fig. 3 shows the least developed drawing of a plan view and Fig. 4 shows the most sophisticated.

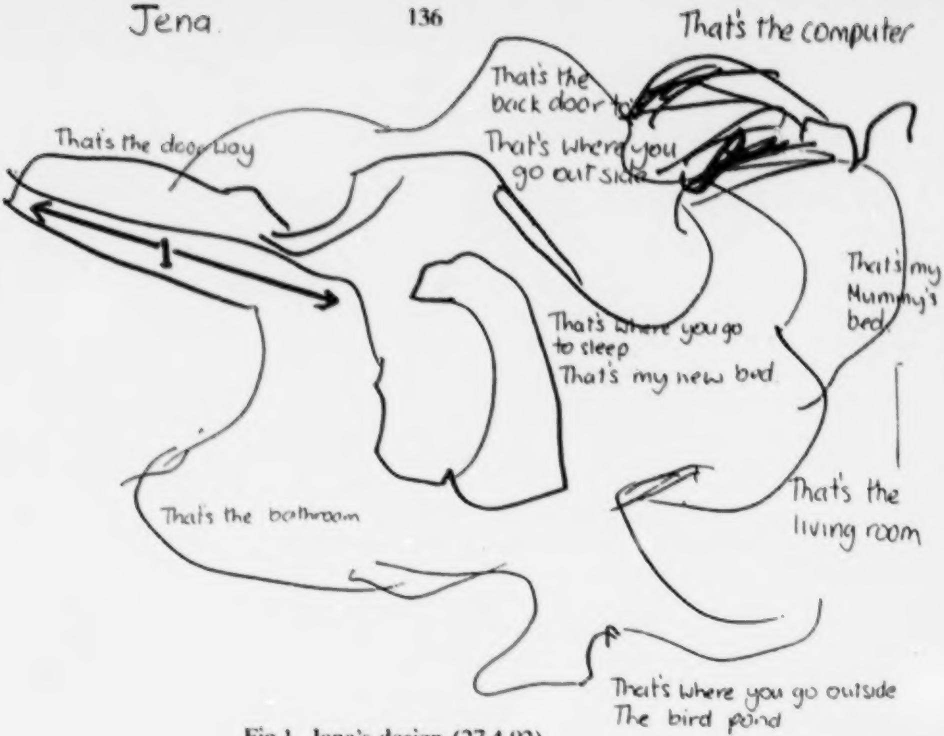
Jena
That's the computer
That's the back door to
That's the door way
That's where you go out side
1
That's my Mummy's bed
That's where you go to sleep
That's my new bed
That's the bathroom
That's the living room
That's where you go outside
The bird pond

Fig.1 Jena's design (27.4.92)

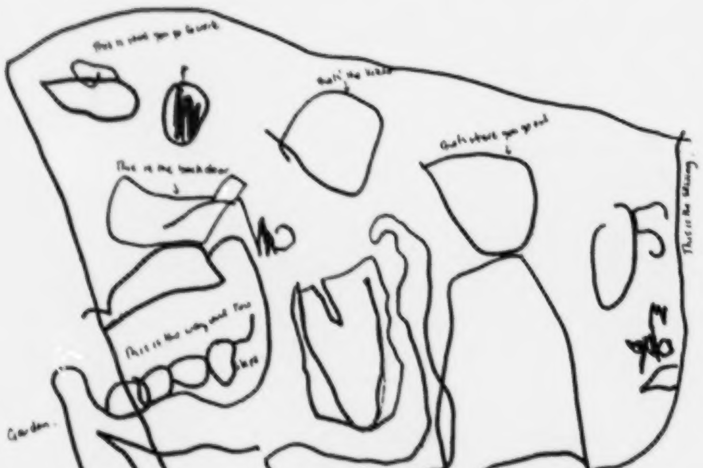
This is where you go to work
That's the table
This is the back door
That's where you go out
This is the way and Two
Steps
Garden.
This is the living
This is the play room

Fig.2 Jena's design (4.5.92)

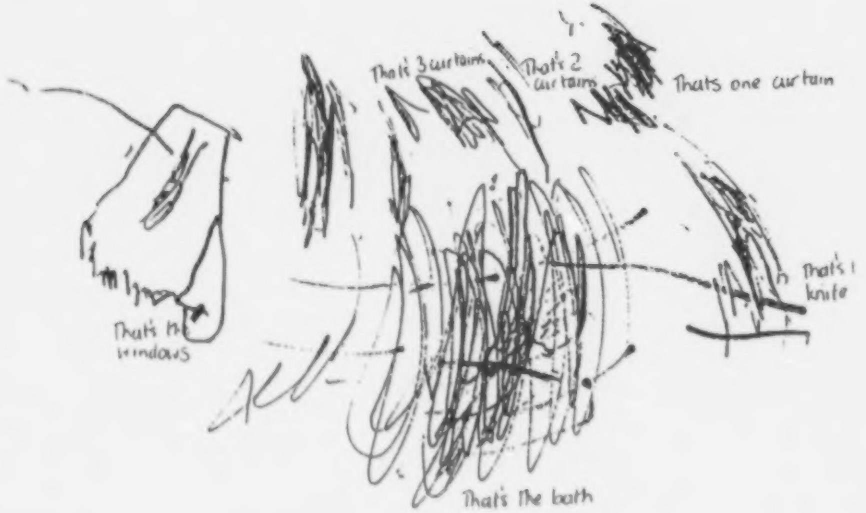
That's 3 curtains
That's 2 curtains
Thats one curtain
That's the windows
That's 1 knife
That's the bath

Fig.3 Imogen's design (30.4.92)

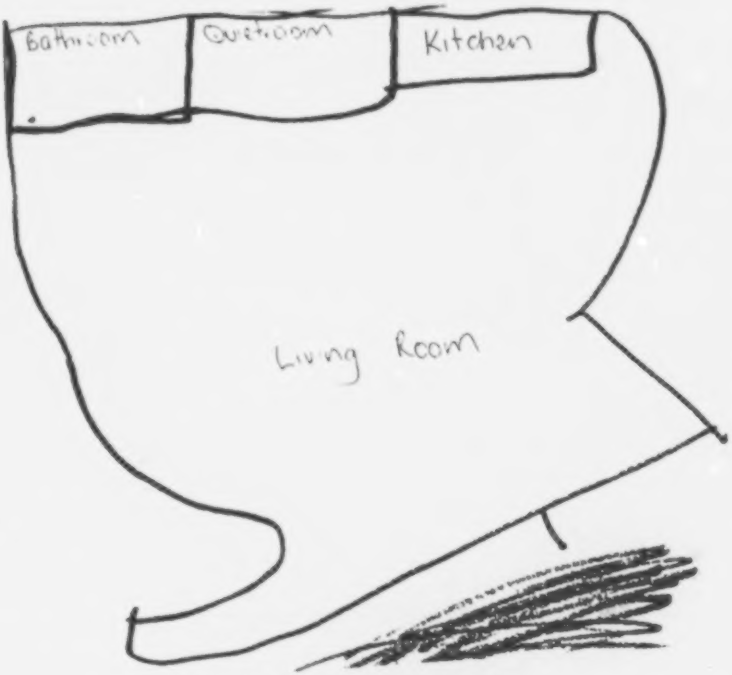
Bathroom
Guestroom
Kitchen
Living Room

Fig.4 Lucy's design (7.5.92)

Children using their designs to construct

The analysis of video data indicated that only a few children were able to accurately build their plan view. In addition, it was not until the latter part of the study that children were able to draw their plan view prior to house construction. The video data indicated that the children's floor plans were not located near their constructions until Day Five of the data collection phase. Prior to that time only a relatively small number of children took their plans to the block area, or drew immediately after constructing (in an attempt to record their construction). This was expected since the children needed many opportunities to have modelled to them the design and construction phase of the approach.

Fig. 5 shows that Jessica was able to operate effectively in the block area following the design, make and appraise approach to technology education. She worked together with Lucy, who also had drawn an accurate plan of the Creche. They both made regular references to their floor plan as they constructed, revising as they built. An interesting observation made from the video data was that both Jessica and Lucy were building with a different north-south orientation. As a result, a great deal of negotiation and discussion resulted (Jessica took the leading role in the construction work, which meant that Lucy co-operated by following her re-orientation.) Although not all children developed their skills to this level, it is evident from the floor plan and construction that the design, make and appraise approach can be implemented successfully with pre-school children.

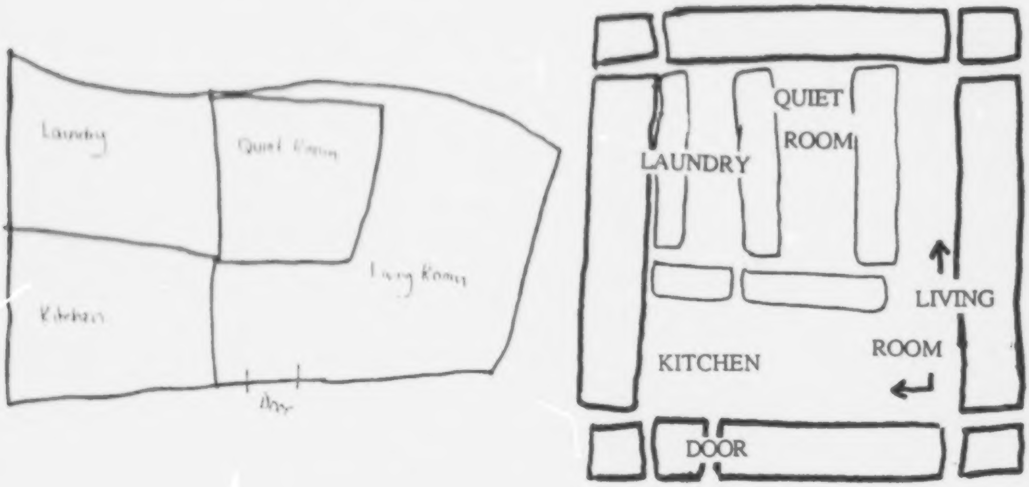

Fig.5 Jessica's design and construction

CONCLUSION

The data clearly showed young children's limited representational skills at the commencement of the learning sequence. As a consequence children had modelled to them the importance of designing before they engaged in construction work as well as drawing their completed constructions. The data also revealed that children's representational skills rapidly developed over the two weeks. This was a direct result of the children engaging in the technology education programme.

It is evident that a design, make and appraise approach to technology education is achievable in early childhood. Children as young as three are able to engage in this process, although to varying degrees of ability. Since technology education is new to most children, explicit attention must be given to introducing the technological process. Its introduction should be through a meaningful experience that has some social purpose for them, for example building the three little pigs' homes. Concurrently, the design, make and appraise elements used should be made clear to children. This can be achieved through the adult modelling each phase, working together with children to achieve this approach and finally handing over responsibility of the process to the children.

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REFERENCES

Australian Education Council (1992). Technology for Australian Schools Interim Statement, Canberra: Australian Government Printing Service.

Beat, K.(1991). Design it, build it, use it: Girls and construction kits, In A. Kelly (ed.) Science for girls Milton Keynes: Open University Press.

Browne, N. (ed.) (1991). Science and technology in the early years. Milton Keynes: Open University Press.

Bruner, J. (1987). The transactional self. In J. Bruner & H. Haste, (eds.) Making sense. The child's construction of the world. New York: Methuen.

Fensham, P. (1990). What will science education do about technology? The Australian Science Teachers Journal, 36 (3), 7-13.

Harding, J. (1983). Switched off: The science education of girls London: Longman Paul.

Kelly, A. (ed.) (1987). Science for girls. Milton Keynes : Open University Press.

Vygotsky, L.A. (1978). Mind in society: The development of higher psychological processes, Cambridge MA: Harvard University Press.

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THE APPLICATION OF SCIENCE TO TECHNOLOGY

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ABSTRACT

The notion that technology is the application of science to the making of artefacts is a widely-held, persistent and influential view. Considerable scholarly work has been done during the past quarter century to refute it on the grounds that it is historically and ontologically inaccurate. It is a view which fails to recognise the contribution of non-scientific factors to technological development, which neglects the reverse contribution of technology to science, and which offers a superficial account of the process of application. This paper focusses on this last point, and argues that in those cases where science is applied to technology, the application process is usually exceedingly complex. The process involves the selection of appropriate knowledge, the adoption of differing criteria and the translation and re-shaping of knowledge to make it amenable to the technologist. The issue has important implications for the school curriculum.

THE TECHNOLOGY-AS-APPLIED-SCIENCE POSITION

...basic research leads to new knowledge... It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science.

Vannevar Bush, US presidential advisor on science policy
(Bush, 1945, pp 13-14).

The technologist must have a tremendous knowledge of science; and he must understand that science which he puts to such good use. Furthermore ... the technologist is sterile: one generation of technologists cannot breed the next generation -- for the latter will be far behind the frontiers, and will lack the deeper understanding which is part of their preparation. It is the pure scientists who must give the next generation of technologists essential training.

Professor Eric Rogers, director, Nuffield Physics Project
(quoted in McCulloch, Jenkins & Layton, 1985, pp 96-97.)

Technology is the application of scientific knowledge to the solution of human problems.

junior secondary textbook for Craft, Design and Technology in England
(Breckon & Prest, 1983, p 46)

[Technology is] the enabling process by which science is applied to satisfy our needs.

British curriculum guide for science teachers
(Holman, 1986, p 23)

> ...technology is an application of the concepts and principles of science.
> Ministry of Education (British Columbia) (1986, p 4)

> Technology has been described in many ways. But most definitions concur that technology is the application of math and science for specific purposes...to make our lives better, more productive or more enjoyable.
> W. B. Waetjen, chairman,
> US Technology Education Advisory Council (TEAC, 1988)

Underlying all of these quotations is a common ontological position: that technological outcomes are the result of applying scientific knowledge. This technology-as-applied-science (TAS) view is widely-held, persistent, influential, and it has distinguished intellectual ancestry. The 17th century scholar, Francis Bacon, in his Novum Organum, was a powerful advocate for the idea that technology ought to be applied science. "Nature, to be commanded, must be obeyed", he wrote; science was to provide the knowledge of nature that technology would then use for human betterment. It was an argument which would be used to underpin the establishment of organisations such as the Royal Institution and the British Association for the Advancement of Science, which sought to apply scientific knowledge to the world of practical affairs. Not surprisingly, it is a position which finds much favour among the science research funding lobby. It finds its way into school science textbooks in which technological artefacts are offered as illustrations of scientific principles, the unstated implication often being that the artefact was developed through the application of those principles (Gardner, 1990).

CRITICAL ATTACKS ON THE TAS POSITION

Despite the confident assertions about the equivalence of technology and applied science, the TAS view is a philosophical position, and not an established fact. It is a view which has been subjected to considerable scholarly attack during the past 30 years (but remains firmly entrenched, nevertheless). The grounds of the attack are that the TAS position is untenable on both historical and ontological grounds.

Space does not allow for the details of this attack to be elaborated here; a mention of some of the key scholars, institutions and journals will have to suffice. Alexandre Koyré (1948) was an early critic of the traditional view; his essay, published in France, argued that technology was an independent system of thought which differed from science. A decade would elapse before similar challenges would emerge on the other side of the Atlantic, with the formation of the Society for the History of Technology in 1958, and the inception of its journal, Technology and Culture, the first to specialise in the history and philosophy of technology. Many papers in its second, 1961, volume challenged the conventional wisdom of the TAS view. In 1962, it published the proceedings of a conference sponsored by The Encyclopaedia Brittanica; science/technology relationships were among the topics discussed. Three years later, the journal devoted a whole issue to this topic; the papers included a seminal article by Derek de Solla Price (1965) ("Is technology historically independent of science? A study in statistical historiography") which argued that the two fields had developed largely independently, with only occasional contributions from science to technology, usually with a long time gap, i.e. the science was "old science".

In 1965, the Society organised a symposium on "Toward a Philosophy of Technology"; papers and comments were published in Technology and Culture the following year. One contributor (Skolimowsky, 1966) attacked the TAS position unequivocally. He noted that it was the business of epistemology "to investigate the peculiarities of technology and its relation to other forms of human knowledge", especially its relation to science, and went on to argue "(1) [that] it is erroneous to consider technology as being an applied science, (2) that technology is not science, (3) that the difference between science and technology can best be grasped by examining the idea of scientific progress and the idea of technological progress" (p 372).

A generation has passed since the beginnings of this rethinking of the science/technology relationship, and much has been written in the intervening period. Nevertheless, the TAS view continues to dominate many people's thoughts about technology. The opening words of a recent book (Vincenti, 1990) on the nature of engineering knowledge clearly recognise the persistence of the TAS view:

> Engineering knowledge, though pursued at great effort and expense in schools of engineering, receives little attention from scholars in other disciplines. Most such people, when they pay heed to engineering at all, tend to think of it as applied science. Modern engineers are seen as taking their knowledge from scientists and, by some occasionally dramatic but probably intellectually uninteresting process, using this knowledge to fashion material artefacts. From this point of view, studying the epistemology of science should automatically subsume the knowledge content of engineering. Engineers know from experience that this view is untrue, and in recent decades historians of technology have produced narrative and analytical evidence in the same direction. Since engineers tend not to be introspective, however, and philosophers and historians (with certain exceptions) have been limited in their technical expertise, the character of engineering knowledge as an epistemological species is only now being examined in detail (p 3).

Vincenti went on to argue that technology is a form of thought which "though different in its specifics, resembles scientific thought in being creative and constructive; it is not simply routine and deductive as assumed in the applied-science model. In this newer view, technology, though it may apply science, is not the same as or entirely applied science" (p 4). The view that the knowledge content of technology comes from science

> immediately defines the science-technology relation -- technology is hierarchically subordinate to science, serving only to deduce the implications of scientific discoveries and give them practical application. This relation is summarized in the discredited statement that "technology is applied science." Such a hierarchical model leaves nothing basic to be discussed about the nature of the relationship. A model with such rigidity is bound to have difficulty fitting the complex historical record (p 5).

Criticisms and consequences of the TAS view

There are two major lines of argument against the TAS view. The first is historical: its central thrust is that technology has developed throughout the ages largely without the benefit of scientific knowledge. Historians critical of the TAS view point to the enormous numbers of artefacts (windmills, water wheels, bridges, sailing ships, barbed wire, pencils....) developed without scientific input. Often, when there has been a link between technological capability and scientific knowledge (lens manufacture and laws of refraction, steel making and chemical theory), the technology has preceded the science. The second is ontological; its central thesis is that technological capability is a necessary precursor to scientific conceptualisation, that thought is a consequence of praxis. On this argument, medieval developments in clock-making laid the foundation for our modern concept of time; moreover, experience with clockwork mechanisms provided a fruitful metaphor for the later Newtonian model of the universe. The recent writings of Ihde (1983, 1991) are prominent in this field.

Associated with the TAS view are a number of intellectual positions, many of which are open to critical challenge. Through its emphasis on formalised scientific thought, the TAS view fails to give adequate recognition to the role of other, non-scientific factors, such as the crucial role of design in technological innovation, the importance of trial-and-error, and the influence of societal (cultural, political, economic) forces in shaping a line of technological development. It leads to an "idealist" reading of the history of science and technology, in which prominence is given to ideas (the revival of the "Greek scientific spirit" in the Renaissance) and the vital contributions of medieval technology are ignored. It tends to neglect the crucial role of instrumentation in science, not merely as a tool, but as a shaper of thought; it fails to give credit to the part that technology has played in generating new questions for scientific research.

Even in cases where a technological innovation does make use of prior scientific knowledge, the issue of application is often treated superficially, as if this were an obvious rather than a complex process. This issue is the focus of the present paper.

AN ANALYSIS OF 'APPLICATION'

Application as algorithm

One immediate problem in this discussion is that 'application', like many other abstractions in the English language, has a wide range of connotations. In scientific and mathematical contexts, it is often used to refer to the process of using an algorithm ($[a + b]^2 = a^2 + 2ab + b^2$) or a scientific law statement (Ohm's law) to deduce a correct answer to a well-defined question. Thomas Edison's request to his applied physicist, F. Upton, to calculate the amount of copper needed to implement his electric street-lighting proposal (Agassi, 1966) exemplifies this meaning of 'application'. If one knows the relevant formula or law, it is a straightforward matter to use it to obtain a correct answer. Some writers seem to believe that this simple connotation of 'application' successfully accounts for all cases of science-based technology. Thus, a century ago, Henry Rowland (1848-1901), who trained as an engineer and later became a professor of physics at Johns Hopkins University, could write that:

> It is not an uncommon thing especially in American newspapers, to have the applications of science confounded with pure science; and some obscure American who steals the ideas of some great mind of the past, and enriches himself by the application of the same to domestic uses, is often lauded above the originator of the ideas, who might have worked out hundreds of such applications, had his mind possessed the necessary element of vulgarity (quoted by Finch, 1961, p 326).

The implicit belief underlying this extraordinary statement is that it is simple to turn a scientific idea into a technological application.

Application as selection

Actually, the connections between the ideas that form part of a body of scientific knowledge and their embodiment in a practical outcome are seldom self-evident. The technologist wishing to apply scientific knowledge to the solution of a technological problem must often first decide which knowledge is appropriate. Bunge (1966, p 333) notes that artefact construction frequently does not require the application of all the scientific knowledge available in the field at any given time. Most modern optical instruments, for example, can be adequately designed with a knowledge of 16th century ray optics; wave theory can be drawn upon to explain, in outline but not in detail, other effects -- mostly undesirable -- such as chromatic aberration. Wave equation descriptions of events such as the movement of a camera shutter are of purely academic interest, of no concern to the camera designer. Thus judgements have to be made about what knowledge to select.

Application involves adopting differing criteria

The difficulty in applying scientific knowledge to practical outcomes is exacerbated by the very form of that knowledge. Science is concerned with precisely defined variables, with knowledge of relationships obtained under controlled conditions. In real situations, however,

> the relevant variables are seldom adequately known and precisely controlled. Real situations are much too complex for this, and effective action is much too strongly urged to permit a detailed study -- a study that would begin by isolating variables and tying some of them into a theoretical model (Bunge, 1966, p 335).

Scientific demands for precision are sometimes unnecessary in technology. Artefacts can often be successfully designed and made without (or even despite) scientific precision, because the "accuracy requirements in applied science and practice are far below those prevailing in pure research so that a rough and simple theory supplying quick correct estimates of orders of magnitude very often will suffice in practice" (p 334).

Application requires the translation and reshaping of knowledge

Before a technologist can make use of a scientific idea, that idea must often be translated into a more useable form. This can be an exceedingly complex process, and may include any of the following:

- translation from one language to another;
- translation from "physicists' language" to "engineers' language";
- translation from the inventor's idea through to design, prototype and final manufactured product; frequently, additional technical problems have to be surmounted along the way.

Scientists and technologists may use different forms of language in describing their work; successful application may first require someone to act as an interpreter. (Sometimes, this is literally true: some of the early mathematical treatises on the ideal shape of gear wheels were written in Latin, totally unintelligible to the average millwright!) Feibleman (1961) notes that modern theories, especially in physics, are

> of such a degree of mathematical abstraction that an intermediate type of interest and activity is now required. The theories which are discovered in the physicists'

> laboratories and published as journal articles take some time to make their way into engineering handbooks and contract practices. Some intermediate theory is necessary for getting from theory to practice (p 309).

Even when scientists deliberately set out to help technologists solve practical problems, the form of communication may inhibit effective application. James Clerk Maxwell, for example, did pioneering work on electromagnetic theory; he also did some important work on the analysis of stresses in frameworks and attempted to solve practical problems. However, his publications in both fields first had to be "translated" before they could be used by engineers. Translation often involves "extensive reformulation and an act of creative insight" (E. Layton, 1971, pp 577-578).

The development of the direct-current dynamo during the 19th century provides another illustration. Henry Rowland, mentioned earlier, pursued "pure" research and published some important work on magnetic permeability and the mathematics of electromagnetic circuits. He failed to make practical use of his findings, although they were relevant to improving the design of the d.c. dynamo; he seemed to be more interested in discovering laws of nature than industrial design principles. Meanwhile, a practising engineer in England, John Hopkinson, working in co-operation with Thomas Edison, had devised a graphical method of describing dynamo behaviour which allowed major improvements to be made, by changing the dimensions of some of its parts (Mayr, 1971; E. Layton, 1971). (There is some delightful irony here in the light of Rowland's disparaging remarks about the vulgarity of inventors who "stole" the ideas of pure scientists!)

The re-shaping of scientific knowledge for technological purposes often requires additional skills (e.g. engineering skills) which are not deducible from the scientific knowledge being applied, a point already recognised in 1922 by J. D. North, a British aeronautical engineer, in a paper given to the Royal Aeronautical Society:

> Aeroplanes are not designed by science, but by art in spite of some pretence and humbug to the contrary. I do not mean to suggest for one moment that engineering can do without science, on the contrary it stands on scientific foundations, but there is a big gap between scientific research and the engineering product which has to be bridged by the art of the engineer (cited by Vincenti, 1990, p 4).

Vincenti goes on to comment that it is the creative and constructive knowledge of the engineer which is needed to implement that art; technological knowledge "in this view appears enormously richer and more interesting than it does as applied science" (p 4).

Translation of knowledge into artefact may be difficult because the scientific knowledge was gained under idealised or laboratory-scale conditions; applying it to real-life, full-scale conditions may first require the surmounting of additional problems. A.R. Hall (1961) notes that the 17th century Danish astronomer Ole Roemer and members of the French Academy of Sciences had worked out that gear teeth would mesh more accurately if they had epicycloidal profiles, but this was of no practical value to millwrights (even had they known of the research), since they lacked the machinery for cutting suitable material. Wood could have been cut to shape, but was unsuitable for gear teeth, while iron was impossibly difficult to work except on a small scale.

The history of the extraction of aluminium provides a second illustration of this point. Hans Christian Oersted first obtained traces of impure aluminium in 1825 by mixing potassium-mercury amalgam with anhydrous aluminium chloride; two years later, Friedrich Wohler tried a similar reaction, using potassium in place of the amalgam. By 1854, H. St. Claire Deville had made some aluminium leaf electrolytically. However, practical exploitation of this knowledge by Charles H. Hall in the United States and (independently) P.L.C. Héroult in Switzerland took another thirty years, and large-scale commercial exploitation another twenty years. Viability depended upon the development of other technologies, namely the Bayer process for concentrating the aluminium oxide used as the raw material, and the electric furnace and the dynamo for producing high temperatures and currents. The first commercial production, through the electrolysis of aluminium oxide dissolved in molten sodium-aluminium fluoride, was carried out in Pittsburgh in 1888, but the yield was small, limited to about 20 kg per day. Mass production was not possible until cheap hydroelectric power became available in the early 1900s (Rae, 1960; Bronowski, Barry, Fisher & Huxley, 1963, p 118; M.B. Hall, 1976).

The basic technology of the jet engine was known to Hero of Alexandria in the 1st century, when he used a jet of steam in his toy "aelopile". Rockets have been in use for military and other purposes since the 13th century. The basic physics -- Newton's action-reaction law -- was elucidated in the 17th century, and the specific idea of a gas-driven turbine was put forward late in the 18th century. However, when, in 1929, a 22-year old RAF cadet named Frank Whittle conceived of applying the gas turbine to jet propulsion,

> he still had a dozen years of frustrating effort ahead of him before he had an engine operating in actual flight. His difficulties were not matters of fundamental principle, but technical points like the proper setting of turbine blades or the control of air turbulence in the compressor (Rae, 1961, p 397).

Finally, the process of moving from invention through to prototype and commercial product is often very complex, requiring skills not necessarily possessed by the scientist or inventor. Rabi (1965) was a distinguished US physicist involved in developing microwave radar during the second world war, and was close to people engaged in other major projects (the atomic bomb, the transistor, the maser and the klystron tube). He argues that the process of translating a scientific idea into a technological product involves many diverse steps, each usually requiring people with highly specialised abilities. The ability to conceive of an invention, he argues, is very different to the ability to see through the numerous details of the process of making it. Before the magnetron tube could be manufactured, several men spent months finding out "how to describe it, to reduce it to drawings, so that it could be properly made by the manufacturers" (p 12). A prototype could then be constructed in the model shop; the next task "was to break down the stages of production into simple procedures so that the magnetron could be made economically and in such a way that each one would work the way it was supposed to" (p 13). Rabi likens the harmonious co-ordination of this process to the conducting of a symphony orchestra.

IMPLICATIONS FOR SCHOOL CURRICULA

An obvious implication of all this is for curriculum content itself, for the story we tell students about the nature of science and technology. Although the simplistic TAS view has been thoroughly discredited for over quarter of a century, the arguments have tended to remain in academic journals and scholarly books; they have not generally found their way into science teacher education programs, school texts and classroom practice. There are three important consequences of this. One is that as long as technology is perceived as an offshoot of science, instead of as a complex field worthy of study in its own right and on its own terms, science will continue to be regarded as the more powerful and hence more socially valued area of study. A second is that students not intending to proceed with further studies in technological fields may leave school with a distorted view of the nature of technology. The third is that students wishing to proceed in this area may be guided into it, and selected for it, on the basis of abilities and interests in scientific and mathematical fields which are only partly relevant to the education of technologists. A decade ago, George (1981, pp 25-26), an engineer, criticised high school curricula in which students are taught "physics, chemistry and biology as abstract, self-significant science which understandably come to represent the whole of science in their minds... Engineering and the work of engineers remains obscure. At best, engineers are thought to apply science (physics, chemistry, biology) and mathematics to some practical ends". Students typically ended their secondary education "with a distorted view of science and virtually no concept of engineering and technology" (p 26). George was writing about education in Canada a decade ago, but his criticisms apply equally well to Australia today.

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REFERENCES

Agassi, J. (1966). The confusion between science and technology in the standard philosophies of science. Technology and Culture, 7, 348-366.

Breckon, A. & Prest, D. (1983). Introducing Craft, Design and Technology. London: Thames/Hutchinson.

Bronowski, J, Barry, Sir Gerald, Fisher, J & Huxley, Sir Julian (eds) (1963) Technology: Man remakes his world London: Macdonald

Bunge, M. (1966). Technology as applied science. Technology and Culture, 7, 329-347.

Bush, V. (1945). Science, the endless frontier: a report to the President. Washington DC: US Government Printing Office.

Feibleman, J.K. (1961). Pure science, applied science, technology, engineering: an attempt at definitions. Technology and Culture, 2 (4), 305-317.

Finch, J.K. (1961). Engineering and science: a historical review and appraisal. Technology and Culture, 2 (4), 318-341.

Gardner, P.L. (1990). The technology-science relationship: some curriculum implications Research in Science Education, 20, 124-133.

George, D.A. (1981). An engineer's view of science education Toronto: University of Toronto Guidance Centre/ Science Council of Canada/ Canadian Government Publishing Centre

Hall, A.R. (1961). Engineering and the scientific revolution. Technology and Culture, 2 (4), 333-341.

Hall, M.B. (1976). The strange case of aluminium. In A.R. Hall & N. Smith (eds) History of technology Vol. 1. London: Mansell, pp 143 -157.

Holman, J. (1986). *Science and Technology in Society: a general guide for teachers*. Hatfield, Herts: Association for Science Education.

Ihde, D. (1983). The historical-ontological priority of technology over science. In P T Durbin & F Rapp (eds) *Philosophy and technology* (Boston Studies in the Philosophy of science, Vol. 80) Dordrecht, Holland: D Reidel Publishing Company

Ihde, D. (1991). *Instrumental realism* Indiana University Press

Koyré, A. (1948). Du monde de l'à peu prés à l'univers de la précision. *Critique*, *4* No. 28

Layton, E. (1971). Mirror image twins: the communities of science and technology in 19th-century America. *Technology and Culture*, *12* (4), 562-580.

McCulloch, G., Jenkins, E. & Layton, D. (1985). *Technological revolution? The politics of school science and technology in England and Wales since 1945*. London: Falmer Press

Mayr, O. (1971). The Chicago Meeting, December 26-30 1970 [of the Society for the History of Technology]. Program Notes. *Technology and Culture*, *12*, 238-240.

Ministry of Education [British Columbia] (1986). *Science and Technology 11: curriculum guide*. Victoria, BC: Schools Programs, Curriculum Development Branch

Price, D. de S. (1965). Is technology historically independent of science? A study in statistical historiography. *Technology and Culture*, *6* (4), 553-568.

Rabi, I.I. (1965). The interaction of science and technology. In A.W. Warner, D. Morse & A.S. Eichner (eds), *The impact of science on technology*. New York: Columbia University Press, pp 9-36.

Rae, J.B. (1960). The "know-how" tradition: technology in American history *Technology and Culture*, *1* (2), 139-150

Rae, J.B. (1961). Science and engineering in the history of aviation. *Technology and Culture*, *2* (4), 391-399.

Skolimowsky, H. (1966). The structure of thinking in technology. *Technology and Culture*, *7*, 371-383.

TEAC [Technology Education Advisory Council] (1988). *Technology: a national imperative*. Reston VA: International Technology Education Association.

Vincenti, W. G. (1990). *What engineers know and how they know it*. Baltimore & London: Johns Hopkins University Press.

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THE HISTORICAL ANECDOTE AS A "CARICATURE": A CASE STUDY

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ABSTRACT

Much discussion has recently taken place about uses which can be made of historical material in science teaching. A great deal of advice, taking advantage of the particular and unique contributions which the history of science can make to science education, is available.

The encounter between Thomas Huxley and Bishop Wilberforce in 1860 is frequently referred to when teaching about the theory of evolution and an investigation of the main characteristics of reports of this incident in both educational and historical literature has been carried out. The purposes of using this incident in the educational setting are identified and the appropriateness of these purposes is discussed in the light of a historical understanding of this encounter.

INTRODUCTION

Historical anecdotes have two major functions in science teaching (Gauld, 1977). The disciplinary function of the anecdote is to help in the teaching of scientific concepts and the historical dimension is simply a vehicle for conveying information about the meaning of scientific terms, of providing evidence for the point of view being taught (such as Darwin's theory) or against a view being rejected (such as Lamarck's). A more recent rationale for using history in this way is based on the similarities which appear to exist between the ideas of pupils and those now discarded ideas of early scientists (Gauld, 1991). Evidence which brought about changes in the ideas of the scientific community in the past is used to produce similar changes in the ideas of school pupils today. In some cases the disciplinary function of historical anecdotes may be based not on their conceptual content but simply on their motivational value - their appeal as "interesting stories".

The cultural function of historical anecdotes focuses attention on the more humanistic aspects of science - on the way people do science, on the way evidence is evaluated and how it affects the theoretical commitments of scientists, on the interactions between science and society and so on.

The claim that a historical anecdote represents history is more important when it functions in the second sense than for its disciplinary function. It may convey scientific concepts quite adequately whether or not the account is historically accurate but what it conveys in its cultural role will be severely distorted if care is not taken to ensure a certain degree of historical integrity.

In this paper the functions and characteristics of reports, in both the educational and historical literature, about the encounter between Samuel Wilberforce, Bishop of Oxford, and Thomas Henry Huxley at the 1860 meeting of the British Association, are examined.

THE ENCOUNTER

Since the centenary, in 1959, of the publication of Darwin's The Origin of Species much information has become available about the encounter and what took place. In its report of the meeting (Section D of the British Association conference on Saturday 30 June 1860) at which the encounter took place The Athenaeum of 14 July 1860 reported speeches by nine people. The "keynote" address by Professor J.W. Draper was entitled "On the intellectual development of Europe, considered with reference to the views of Mr. Darwin and others, that the progression of organisms is determined by law", Wilberforce's and Huxley's speeches were the fourth and fifth reported and Joseph Hooker's the ninth. Although the newspaper reports were brief, reconstructions of Wilberforce's presentation, based on newspaper reports and on his review in the Quarterly Review of July 1860 (Wilberforce, 1860), are available (Gauld, to be published; Jensen, 1988; Lucas, 1979; Phelps & Cohen, 1973; Wrangham, 1979) showing that it reflected the scientific concerns that people of the day had with Darwin's book. Writing to Hooker in July 1860 about Wilberforce's review essay of The Origin of Species Darwin admitted "It is uncommonly clever; it picks out with skill all the most conjectural parts, and brings forward well all the difficulties" (Darwin, 1888, Volume 2, p.324-5). Later, in a letter to Lyell, Darwin commented that "the Bishop makes a telling case against me, by accumulating several instances where I speak very doubtfully" (Darwin, 1888, Volume 2, p.332). During the course of Wilberforce's speech he asked a rhetorical question about the implications of Darwin's theory for Huxley's simian ancestry and Huxley responded with references to Wilberforce's alleged misuse of oratorical skills and with comments on some of the scientific issues Wilberforce had raised. The repartee caused quite a stir at the meeting but was not reported in any of the newspapers. There is strong evidence that Huxley's speech was not sufficiently compelling to counteract that of the Bishop but Hooker's, later in the session, was much more effective in defending Darwin's position against the Bishop's arguments (Gilley, 1981; Huxley, 1918, Volume 1, p.526). Indeed the report, in The Athenaeum, of Hooker's speech occupied about three times the space devoted to that of Huxley (or of Wilberforce).

The above encounter could be used to serve a disciplinaryfunction in teaching as a source of criticisms of Darwin's theory and of Darwinian responses to them with a view to providing a clearer account of the nature of the theory of evolution. Along with this is the role of the encounter as the basis for a entertaining story. Alternatively, it could serve a cultural function in focussing on the interaction between science and society in the mid-nineteenth centuryover the theory of evolution and on the course of that interaction into the early years of the 20th century.

THE REPORTS OF THE ENCOUNTER

References to the Wilberforce-Huxley encounter were found in 63 books. The earliest report was dated 1896 (republished in 1960) while the latest was 1991. Half were published after 1974. The list includes twelve biographies of Darwin (including one biographical novel) and three of Huxley. Thirteen books, identified as "technical", dealt in depth with particular aspects of Darwin's thought, the nature of the Darwinian revolution, or influences of Darwin's theory on later generations. Of reports in the more educational literature, 11 were encyclopedia entries dealing with the life of Darwin or Huxley, 17 were in relatively popular expositions of the history of science, history of biology or of the theory of evolution and 7 were in school or university texts.

The structure of the accounts

Word lengths of the 63 accounts of the Wilberforce-Huxley encounter ranged from 10 to almost 3000 words. The median length is just over 200 words while the mean is just under 500 words. The longer accounts tend to be found in the biographies of Darwin and Huxley and technical works while the shorter accounts tend to be found in encyclopedias, texts and the more popular works.

Seven of the accounts do not report anything of what was said. Fifty-one mention the repartee while only 15 of the 63 report anything of what was said in the speeches (besides the repartee). Of these 11 occur in the biographical or technical area. In 45 there is no mention at all of Hooker or his contribution while in only 10 is there any suggestion that Hooker's might have been the more effective response to Wilberforce's arguments.

The contexts of the anecdote

In the literature reviewed the anecdote is set in a variety of contexts. The most frequent setting, occurring in 48 of the 63 accounts, is a discussion of the initial reception of The Origin of Species and the opposition, both scientific and religious, which its publication engendered. In 23 of the 28 biographical or technical accounts this is the main setting. A further two are set in a discussion of Huxley's role as Darwin's defender (Darwin's "bulldog"). Of the other three accounts one emerges from a discussion of Darwin's health (he was at a health "resort" during the British Association meeting in 1860), one relates to an outline of the history of the Oxford University Museum in which the meeting was held, while the third (in the biographical novel) is a gathering at Darwin's home to report on the meeting.

In 25 of the 35 more educational books (encyclopedias, popular presentations and texts) the setting is a discussion of the opposition to Darwin's book. The 7 references to Huxley as Darwin's defender all occur in encyclopedia entries about Huxley. The remaining 3 references relate to Huxley's long running opposition to the views of Owen the anatomist (Wilberforce is presented as Owen's spokesman at the meeting), to a consideration of Huxley's personal characteristics or to a discussion of the relative status of three theories for present biological diversity - special creation, spontaneous generation and transmutation of species (evolution). In this last mentioned text the encounter is used to illustrate the thesis that

> mixing science and religion is always unfortunate, for it makes an objective weighing of the evidence pro and con virtually impossible; the emotional attachment is simply too strong (Baker & Allen, 1979, p.459).

Comments on the effects of the encounter

While the reports of the encounter are largely part of a wider discussion of initial opposition to Darwin's The Origin of Species, comments on the effects of this encounter are less uniform. Ten of the 63 authors make no reference either to the immediate outcome of the encounter on the audience or to the longer term outcome within the history of science in the second half of the 19th century. Twenty-five authors make some reference to both these outcomes and another 28 to either the immediate or the longer term outcome (but not to both). Twenty-three of the 43 comments about the immediate outcome refer to Huxley's triumph or to Wilberforce's defeat (or to both), while another 11 mention the excitement and the uproar which followed Huxley's speech. Nine authors (all in the biographical or technical area) comment that the outcome was somewhat ambiguous or uncertain and imply that it was not clear who the audience judged to be the "winner".

Sixteen of the 35 authors who comment about the long term significance of the event (some authors make more than one comment) state that it represented a defeat for religion (or the Church) by science, 12 claim that it gained a hearing for evolution when the climate of opinion was against it, while 7 see it as the beginning of the public opposition to Darwin's theory. For 2 it established the importance of Darwin and Huxley, for 2 it changed no one's opinions at all and for 2 it was simply a significant episode in the history of science.

A summary of the accounts

Thus, the major emphasis in these accounts of the incident, and especially those in the educational literature, is not so much on scientific criticisms of The Origin of Species as on the reactions to the book and, in particular, the response from the Church. The anecdote serves an almost exclusively cultural function in the educational literaturesurveyed. In fact, any possible value which might lie in the scientific substance of the speeches is usually nullified by references to Wilberforce's alleged ignorance, to his scientific blunders, to his need to be coached (badly it appears) by Owen, and on his use of oratorical techniques, scoffing tone, ridicule and insolence in place of substantial argument. On the other hand, Huxley is portrayed as sober and grave as he succinctly explained Darwin's ideas, exposed the Bishop's errors and demolished what few arguments he presented. Little detail is provided about what he said because the judgement has already been made that there was no scientific substance to what Wilberforce said.

The accounts possess an internal logic of their own in which they play down the importance of any substantial criticism of Darwin's theory, focus on the repartee as the significant aspect of the event and on Huxley as the victor, and overlook the apparently more notable contribution of Hooker to the occasion.

Even a cursory glance at reports of the encounter should make clear that Huxley's clever reply to Wilberforce's clever question, considered impartially, can have nothing worthwhile to contribute to the debate over the status of Darwin's theory. It is simply concerned with etiquette and good manners. A rational judgement about the outcome can only be made on the basis of what was said in the other parts of the speeches and about this most of the reports are, unfortunately, silent.

A BRIEF HISTORY OF THE ANECDOTE

It is interesting that, while there were brief newspaper reports of the content of the speeches (especially summaries in The Athenaeum, of speeches by Wilberforce, Huxley and Hooker) there was no mention at all of the repartee. In the almost 30 years following the event, the only public reference to the repartee seems to be that in Macmillan's Magazine of December 1860.

The accounts which form the source for most future references to the event are those by Huxley and Hooker recalled in 1886 for the publication, two years later, of Darwin's Life and Letters (Darwin, 1888, Volume 2, pp.320-325; see also Huxley, 1900, Volume 1, pp.182-188; Huxley, 1918, Volume 1, pp.525-527; Volume 2, pp.300-304).

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The anecdote emerges, then, as very much dependent on how Huxley and Hooker saw the event and the form in which it appears today represents their reconstruction of the occasion (Browne, 1978; Gilley, 1981). Even Hooker's apparently more decisive role, affirmed by him in a letter to Darwin two days after the meeting (Huxley, 1918, Volume 1, p.526), was down-played in deference to Huxley's version.

The view that the outcome of the encounter was decided on the basis of the repartee depends on a prior conclusion about the relative value of arguments presented by both sides at the meeting. Huxley, Hooker and those who supported Darwin, naturally enough, found Wilberforce's arguments objectionable and they provide the data upon which today's versions of the event are based. For example, on 2 July 1860 Hooker wrote to Darwin that

> Sam Oxon got up and spouted for half an hour with inimitable spirit, ugliness and emptiness and unfairness. I saw he was coached up by Owen and knew nothing, and he said not a syllable but what was in the Reviews; he ridiculed you badly and Huxley savagely" (Huxley, 1918, Volume 1, p.526)

The next day J.R. Green, a pro-Darwinian undergraduate, described the proceedings to W.B. Dawkins in a letter, parts of which were later published in Huxley's Life and Letters (Huxley, 1900, pp.184,5). He wrote

> ...up rose 'Sammivel', and proceeded to act the smasher;... the smasher got so uproarious as to pitch into Darwin's friends - Darwin being smashed - and especially Professor Huxley... Which being ended - and let me say that such rot never fell from episcopal lips before - arose Huxley, young, cool, quiet, sarcastic, scientific in fact and treatment, he gave his lordship such a smashing as he may meditate on with profit over his port at Cuddesdon (quoted in Gilley, 1981)

However, contrary to the above comments, Wilberforce's speech, rather than reflecting ignorance, prejudice and religious sentiment, in fact encapsulated many of the scientific objections people of his day had to Darwin's book (Gauld, to be published; Lucas, 1979; Oldroyd, 1980, p.132; Wrangham, 1979; see also Hull, 1973).

THE REPORT OF THE ENCOUNTER AS A "CARICATURE"

On 30 June 1860 the encounter appears to have had few of the attributes and effects which came to be associated with it at a later stage and which continue to be associated with it in more recent times. It has become a sketch in which non-essential features are eliminated and those considered to be its essence are emphasised. In the literature it is presented as a dogmatic statement rather as part of a case to be defended. For many authors this sketch seems to have become a symbol by which the triumph of science over religious opposition is announced.

As historically adequate accounts, the majority of the reports of the Huxley-Wilberforce encounter are deficient in four significant ways.

Firstly, rather than attempting to give an impartial account of the occasion and its significance, a perspective which has been based almost exclusively on the perceptions of Huxley, Hooker and their supporters is used. Many of the words used to describe the roles of Wilberforce and Huxley come from letters written by Darwin's supporters and selected for publication from 1888 onwards. There is little attempt topresent a more balanced view of the occasion such as that of Chadwick (1970, p.10-11) or of Lucas (1979).

Secondly, the reduction of the opposition which Darwin's ideas called forth to that of a churchman who had no arguments worth considering belie the strength of scientific criticism of the theory which was widespread in the 1860s. Most of Wilberforce's objections in his review of Darwin's The Origin of Species were scientific or philosophical rather than religious. Even Huxley admitted that

> on the whole, then, the supporters of Mr Darwin's views in 1860 were numerically extremely insignificant. There is not the slightest doubt that, if a general council of the church scientific had been held at that time, we should have been condemned by an overwhelming majority (Darwin, 1888, Volume 2, p.186)

Thirdly, the typical report is inadequate as a symbol of the response of the Church to Darwin's theory. The religious response was not in any way as uniform as is often portrayed. While undoubtedly there was opposition from Christians of various types, Moore (1979) has identified two significant groups of Christians in the years up to 1900 who had little difficulty in accepting Darwin's views. The Christian "Darwinists", who were largely theological liberals, interpreted Darwin's position in a metaphysical sense, while the Christian "Darwinians", who were more theologically orthodox or conservative, accepted Darwin's position with little modification (see also Livingstone, 1978).

Fourthly, it is unlikely that the encounter represented the intellectual victory often claimed for it. However, it may have been a victory for Darwin in another sense. Huxley's son, his biographer and editor of his letters, wrote

> The result of this encounter, though a check to the other side, cannot, of course, be represented as an immediate and complete triumph for evolutionary doctrine. This was precluded by the character and temper of the audience, most of whom were less capable of being convinced by the arguments than shocked by the boldness of the retort ... The importance of the Oxford meeting lay in the open resistance that was made to authority, at a moment when even a drawn battle was hardly less effectual than acknowledged victory. Instead of being crushed under ridicule, the new theories secured a hearing, all the wider, indeed, for the startling nature of their defence (Huxley, 1900, p.189)

In the light of these shortcomings or exaggerations, not only does the typical report of this encounter appear in the literature as a sketch but this sketch possesses all the characteristics and deficiencies of a caricature.

CONCLUSION

Using historical anecdotes to teach about the cultural context of science requires a sound understanding of this context while making reference to history to teach about concepts requires an understanding of the intellectual climate of the time so that arguments can be dealt with in the setting of the historical period in which they occur.

In most reports of the above encounter the cultural context is severely misrepresented and the opportunity which it provides for giving closer attention to the criticisms levelled against Darwin's book is overlooked because of a faulty predisposition towards the value of these arguments.

It has been pointed out on a number of occasions (Klein, 1972; Gauld, 1977) that many of the historical anecdotes used in science teaching are legendary (in much the same way as accounts of the above incident possess the characteristics of a caricature). Science teachers do not possess the time or the resources to reconstruct historical anecdotes in a form which upholds the integrity of the historical evidence for them as the relevant information is scattered throughout a wide variety of books and journals. At present there is little assistance available for teachers who wish to use historical anecdotes more appropriately in their teaching and so there is a desperate need for reliable material which is easily accessible to those who teach science.

REFERENCES

Baker, J.W. & Allen, G.E. (1979). A course in biology, (3rd edn). Reading, Mass.: Addison-Wesley.

Browne, J. (1978). The Charles Darwin-Joseph Hooker correspondence: An analysis of manuscript sources and their use in biography. Journal of the Society for the Bibliography of Natural History, 8, 351-366.

Chadwick, O. (1970). The Victorian church, Part II. London: Adam & Charles Black.

Darwin, F. (1888). Life and letters of Charles Darwin, Volume 2. London: John Murray.

Gauld, C.F. (1977). The role of history in the teaching of science. Australian Science Teachers Journal, 23, 3, 47-52.

Gauld, C.F. (1991). History of science, individual development and science teaching. Research in Science Education, 21, 133-140.

Gauld, C.F. (to be published). Wilberforce, Huxley and the use of history in teaching about evolution. The American Biology Teacher.

Gilley, S. (1981). The Huxley-Wilberforce debate: A reconsideration. In K. Robbins (ed) Religion and humanism. Oxford: Blackwell, 325-340.

Hull, D.L. (1973). Darwin and his critics. Cambridge, Mass.: Harvard University Press.

Huxley, L. (1900). The Life and letters of Thomas Henry Huxley, Volume 1. London: Macmillan.

Huxley, L. (1918). The Life and letters of Sir Joseph Dalton Hooker, Volumes 1 & 2. London: John Murray.

Jensen, J.V. (1988). Return to the Wilberforce-Huxley debate. British Journal for the History of Science, 21, 161-179.

Klein, M.J. (1972). The use and abuse of historical teaching in physics. In S.G. Brush & A.L. King (eds) History in the teaching of physics. Hanover: University Press of New England, 12-18.

Livingstone, D. (1978). Darwin's forgotten defenders. Grand Rapids: Eerdmans.

Lucas, J.R. (1979). Wilberforce and Huxley: A legendary encounter. The Historical Journal, 22, 2, 313-330.

Moore, J. (1979). The post-Darwinian controversies. Cambridge, Cambridge University Press.

Oldroyd, D. (1980). Darwinian impacts. Kensington: New South Wales University Press.

Phelps, L.A. & Cohen, E. (1973). The Wilberforce-Huxley debate. Western Speech, 37, 56-64.

Wilberforce, S. (1860). Review: On The Origin of Species, by Means of Natural Selection, or the Preservation of Favoured Races on the Struggle for Life. By Charles Darwin, M.A., F.R.S., London, 1860. The Quarterly Review, 108, 225-264 (originally published anonymously as was the convention).

Wrangham, R. (1979). The Bishop of Oxford: Not so soapy. New Scientist, 83, 450-451.

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against Darwin's book is overlooked because of a faulty predisposition towards the value of these arguments.

It has been pointed out on a number of occasions (Klein, 1972; Gauld, 1977) that many of the historical anecdotes used in science teaching are legendary (in much the same way as accounts of the above incident possess the characteristics of a caricature). Science teachers do not possess the time or the resources to reconstruct historical anecdotes in a form which upholds the integrity of the historical evidence for them as the relevant information is scattered throughout a wide variety of books and journals. At present there is little assistance available for teachers who wish to use historical anecdotes more appropriately in their teaching and so there is a desperate need for reliable material which is easily accessible to those who teach science.

REFERENCES

Baker, J.W. & Allen, G.E. (1979). A course in biology, (3rd edn). Reading, Mass.: Addison-Wesley.

Browne, J. (1978). The Charles Darwin-Joseph Hooker correspondence: An analysis of manuscript sources and their use in biography. Journal of the Society for the Bibliography of Natural History, 8, 351-366.

Chadwick, O. (1970). The Victorian church, Part II. London: Adam & Charles Black.

Darwin, F. (1888). Life and letters of Charles Darwin, Volume 2. London: John Murray.

Gauld, C.F. (1977). The role of history in the teaching of science. Australian Science Teachers Journal, 23, 3, 47-52.

Gauld, C.F. (1991). History of science, individual development and science teaching. Research in Science Education, 21, 133-140.

Gauld, C.F. (to be published). Wilberforce, Huxley and the use of history in teaching about evolution. The American Biology Teacher.

Gilley, S. (1981). The Huxley-Wilberforce debate: A reconsideration. In K. Robbins (ed) Religion and humanism. Oxford: Blackwell, 325-340.

Hull, D.L. (1973). Darwin and his critics. Cambridge, Mass.: Harvard University Press.

Huxley, L. (1900). The Life and letters of Thomas Henry Huxley, Volume 1. London: Macmillan.

Huxley, L. (1918). The Life and letters of Sir Joseph Dalton Hooker, Volumes 1 & 2. London: John Murray.

Jensen, J.V. (1988). Return to the Wilberforce-Huxley debate. British Journal for the History of Science, 21, 161-179.

Klein, M.J. (1972). The use and abuse of historical teaching in physics. In S.G. Brush & A.L. King (eds) History in the teaching of physics. Hanover: University Press of New England, 12-18.

Livingstone, D. (1978). Darwin's forgotten defenders. Grand Rapids: Eerdmans.

Lucas, J.R. (1979). Wilberforce and Huxley: A legendary encounter. The Historical Journal, 22, 2, 313-330.

Moore, J. (1979). The post-Darwinian controversies. Cambridge, Cambridge University Press.

Oldroyd, D. (1980). Darwinian impacts. Kensington: New South Wales University Press.

Phelps, L.A. & Cohen, E. (1973). The Wilberforce-Huxley debate. Western Speech, 37, 56-64.

Wilberforce, S. (1860). Review: On The Origin of Species, by Means of Natural Selection, or the Preservation of Favoured Races on the Struggle for Life. By Charles Darwin, M.A., F.R.S., London, 1860. The Quarterly Review, 108, 225-264 (originally published anonymously as was the convention).

Wrangham, R. (1979). The Bishop of Oxford: Not so soapy. New Scientist, 83, 450-451.

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RISK-TAKING AND TEACHERS' PROFESSIONAL DEVELOPMENT: THE CASE OF SATELLITE REMOTE SENSING IN SCIENCE EDUCATION.

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ABSTRACT

The introduction of satellite remote sensing into the U. K. National Curriculum for Science, and the tasks facing teachers in bringing about this innovation, are discussed in terms of risk, its evaluation, reduction, and address. Conclusions are drawn about strategies by which teachers can confront the risk involved in curriculum innovation in school science and technology.

INTRODUCTION

In recent years, technology education has been introduced into the mainstream school curriculum in many countries, whether as a free-standing subject or through the enhancement of existing subjects. Two major issues have been the identification of a technology on which to focus that educational provision and the nature of that provision.

Of contemporary importance are the 'key technologies', which have been defined as: 'newly emerged topics in science and engineering which are likely to have a revolutionary impact on an existing product or process or may lead to a revolutionary new product or process' (Meeke, 1989). Typical examples are: new materials e.g. ceramics, composites; biotechnology e.g. transgenics; satellite remote sensing e.g.weather forecasting. The importance of key technologies arises from the considerable impact that they may have on the nature of industrial employment and hence on economies and on the broad implications that they have for personal and social decision taking.

Although there is, as yet, no clear consensus on what a comprehensive technology education might consist of, it is argued that it should be based on a comprehensive view of technology itself. Pacey (1983) has suggested that the practice of technology consists of three elements: the *technical* aspect, in which knowledge and skills are applied by tools and chemicals to resources to produce technological outcomes and wastes; the *organizational* aspect, which involves an understanding of how technological activity and its outcomes are socially organized; and the *cultural* aspect, which involves an awareness of the values and goals which underpin decisions on which technology to develop and how to use the outcomes. A comprehensive technology education might thus involve an address to all three elements of Pacey's (1983) model of technology.

The choice of the key technologies as one focus for a comprehensive technology education would be justified not only because of their industrial and social importance but also because they seem to attract the interest of young people. One key technology which is gradually being introduced into U.K. schools is satellite remote sensing (Gilbert, 1992).

Remote Sensing

In its broadest sense, remote sensing is the collection, storage, processing, and display, of data on the Earth's surface, the near-Earth environment, and space. Such data has been collected for many years by means of aircraft, balloons and telescopes. However, the advent of Earth-orbiting satellites, in either polar or geosynchronous orbits, and space probes, has vastly increased the quality and quantity of data available and greatly reduced the time between the collection and the analysis of that data.

Science education can contribute to technology education, and vice-versa, through the medium of satellite remote sensing in respect of: the principles and operation of the satellites; data about the solar system and beyond; data about the near-Earth environment; data about the Earth's atmosphere and surface. The advent of commercially available pictures derived from satellites e.g. from Landsat, and of reasonably priced equipment with which to collect data directly from meteorological satellites, has enabled science teachers, often in collaboration with geography teachers and others, to introduce remote sensing into the curriculum. Like any innovation in the school curriculum, this has implications for the professional development of the teachers involved and their colleagues.

The professional development of teachers

According to Fullan (1991), any educational change will have three elements, present to varying degrees: the use of new teaching materials; the use of new teaching strategies; the adoption of new beliefs about education. Much of the literature about educational change is concerned with teachers' response to imposed change i.e. cases where the change is formulated independently of individual teachers, who are then required, by some authority, to bring it into classroom use. There are reported to be three stereotypical responses to imposed change (Doyle & Ponder, 1977) on the part of a teacher, to be either a 'stone-age obstructionist', who resists a particular change (or, indeed, any change) in all possible ways, or a 'rational adopter', who can be logically persuaded to adopt a given innovation, or a 'pragmatic sceptic' (evidently the great majority in respect of any particular change) who review any given innovation in the light of existing classroom practice. For any innovation to stand a chance of implementation it must simultaneously show *instrumentality* i.e. there must be a clear blueprint of how the innovation might work in the classroom, *congruence* with existing practice, and *cost* i.e .must show a high return in terms of student reaction and learning relative to the investment of the teacher's time and effort (Mohlman, Coladarci & Gage, 1982). The literature on teacher initiated change is less extensive, perhaps because it is often not signalled to researchers, other than where action research networks exist: Rudduck (1988) thinks it likely that such innovations will be the most thoroughly implemented and long lasting .

The introduction of remote sensing into the curriculum does not neatly fit into either the category of imposed or of teacher-initiated change. Certainly, the U.K. National Curriculum for Science does mention remote sensing, which might support the notion of imposed change, but the level of treatment could vary quite widely, which would support the notion of teacher-initiated change. At the time of the Remote Sensing in Science Education Project (Gilbert, 1992), the theme did not really met the three criteria of Mohlman et al.: there was no blueprint of how it might work in the classroom, the way in which it might relate to existing practice had not been worked out, and the impact on students had not been evaluated. Yet a national survey showed that about 10% of all 5000 UK state secondary schools had equipment to receive meteorological data, and there were some 50 schools in which it was widely used in science classes, often in conjunction with other subjects. How had this come about, given the extensive professional development that a teacher needed to introduce it ie how to: acquire, commission, and maintain equipment; identify an appropriate curricular opening; adopt small group work as a main classroom management framework, and introduce or greatly expand activity-based teaching methods (for there was usually only one set of equipment, collecting live, unedited, data)?

All those teachers involved seemed to be willing to take a risk i.e. 'a hazard; the chance of bad consequences, of loss; exposure to mischance' (Concise Oxford Dictionary, 1982), in order to bring about some curriculum gain. It is part of their nature that risks are hard to evaluate. In this case: the introduction might not receive the support of a school's management; remote sensing might turn out to demand either more conceptual understanding or more advanced practical skills than the teacher could display. The risk to professional status, in the eyes of management and students respectively , was considerable. There are three possible responses to *perceived* risk: avoidance, minimalization, acceptance. The 15 teachers and advisers who attended a workshop of the Remote Sensing In Science Education Project had certainly not avoided the risks. How had they minimalized the risks and/or accepted them? Answers might give some clues to how to encourage the professional development which must accompany the general introduction of such an innovation.

Risk-taking and the introduction of satellite remote sensing

The 15 workshop attenders were each interviewed for 35-60 minutes in a loosely structured format built around the questions: how did you first become involved in remote sensing in schools?; what have you tried to do, so far, involving remote sensing?; how successful have your efforts been?; what factors have influenced your degree of success?; what do you hope to do in the future? The tape recording of each interview was listened through several times before the core answers to the specific questions were transcribed and analysed in relation to the notion of risk, which was a word not introduced into conversations by any of the team of four interviewers. The analyses of five interviews were sent the interviewees concerned for validation and their (minimal) comments incorporated.

Four strategies for disseminating risk could be identified:

- by being seen to respond to pressures within the educational organization, whether it be a support agency e.g. 'When I joined the County Team (as an Advisory Teacher) no-one was addressing the social impact of information technology ... being the last one in, I got the awkward issue' , or within a school e.g. 'I saw a demonstration one evening: I was hooked. It fitted in with the school's Development Plan...we were building up a resource centre';

- by initially adopting the innovation at the margins of the curriculum e.g. 'when I have finished some work and set them their homework, I will switch on if I know that there is a NOAA (polar-orbiting weather satellite) pass coming up...it is very much an informal use' and 'we have satellite club...also, on wet days, kids come in and use the equipment: it's better than kicking their heels in the corridor'

- by having prior technical expertise e.g 'I was a radio ham (amateur operator) and had my own weather satellite (signal reception equipment...I don't work in a school, but I got involved in setting up weather satellite system work in a local school by answering an advert in a newspaper'

- by using recorded rather than live images. In response to the question 'do you feel comfortable with live data coming in?', one teacher said: 'No, you are flying by the seat of your pants...the immediacy of the live data captures my imagination...but pre-recorded material is much better...the kids have something to take away.'

Five ways in which the risks involved had been faced up to were identified i.e.

- by becoming the school expert on remote sensing. e.g. 'other teachers come and watch, but I am the only one that operates the equipment' perhaps because 'electronic things are alien to many teachers...including science teachers...they don't see how it can be used in the curriculum.'

- by acquiring external support e.g. 'the backing of the Dyfed (County) Satellite Project team was invaluable: I wouldn't have been able to develop the ideas otherwise.'

- by obtaining a central curriculum place for remote sensing. This consisted of three overlapping steps. The first was to acquire a timetable slot that was weakly defended e.g. 'I started three Sixth Form age 16-18) General Studies (non-examined) courses on remote sensing'. The second was to utilize the curriculum control vested in the teacher in question e.g. 'In the First and Second Years (age 11-12,12-13) —where I control the science courses —I have developed the theme of telecommunications and linked it to information technology and to meteorology.' The third, perhaps taken after the demonstrable success of the first two, is to aspire to a central curriculum place e.g. 'we have it (remote sensing) in Years 7 and 8 (age 11-12, 12-13) now...a short term goal is to see the rolling programme through to Year 11 (age 15-16)...it is also to see curricular progression from the primary school i.e. Year 6 and below).'

- by demonstrating that 'real science' can be done e.g. 'I realized that there were different ways of working —more like real life —I could access information in large quantities. I saw that we could use real data to solve real problems...they (the students) were able to ask questions that they would never have thought of otherwise.'

- by involving the students actively in the process of innovation e.g. 'It helps to have the kids on your side: they ask other teachers difficult questions. I am in favour of using them as a subversive influence.'

There is no doubt that introducing remote sensing into science education is a major task. As a senior schools' inspector said: 'When I go to a school it is usually to see the idiosyncratic initiative of an individual, for very few people have thought it through as a curriculum strategy' and also: 'Nearly every example of it's (remote sensing's) exciting use is where you give some of the agenda to the pupils. This requires a very self-confident teacher, one who is in command of professional skills —they are not likely to lose control in the classroom —they are the people who will take the risk of using live images. The risk is whether you will actually get an image or not: you have to think on your feet with the pupils'.

Some ways in which the risks could be reduced were evident:

- by engaging in cross-curriculum activities. As one humanities teacher put it: 'we have (professionally) spoken to the scientists literally for the first time in ten years...also the Head of Information Technology got involved'

- by engaging in general staff development. The solutions were sometimes pleasantly unorthodox e.g. 'It has been a Faculty issue to get us all trained —we all started from scratch —the staff trust our Year 8 (age 12-13) pupils to help train the staff and solve problems';

- by involving other teachers. This could be for reasons extrinsic to the task of introducing the innovation into the curriculum e.g.'I didn't see any risk: anyway it was my boss who took the risk by buying the equipment' or more intrinsic to that task e.g. in order to get access to more data 'we are exchanging discs with our deadly rivals (another school) across town'.

Discussion

Satellite remote sensing is a typical key technology and therefore a prime example of a technological outcome around which to base a technology education which is comprehensive in terms of Pacey's (1983) three elements. The full ramifications of such a technology education have yet to be worked out, including its relation to science education (Gilbert, in press). A major step has been taken with the introduction into some schools of equipment to receive directly data from meteorological satellites. This limited innovation falls, as a type, somewhere between an imposed and a teacher initiated change: authority has been willing to finance the purchase of the equipment, yet the complex task of bringing it into the curriculum and into classroom use has been left to the initiative of individuals and groups of teachers (Gilbert, 1992). The small study reported here shows some of the benefits to be gained by such an innovation: it enables science education to be readily coupled to a key technology; it enables teachers to use the processes of science in respect of live data, and lots of that data; it enables active methods of learning to be introduced into science education for real, as opposed to contrived, reasons. However, teachers making this innovation do so being initially unable to meet Fullan's (1991) three features to an innovation, let alone Mohlman et al.'s (1982) criteria for a successful innovation. In attempting to both design and introduce this innovation, the teachers involved have taken considerable risks. This paper has illustrated some of the ways in which they minimalized, and then confronted, these risks, and how they sought to reduce the risks for others.

The issue that remains to be addressed is why they, as individuals, were so attracted to the benefits of remote sensing in their work that they took the risks involved. It may have been that the had previously acquired a tendency to take professional risks: the seeds of a nature versus nurture debate seem evident. Sorrentino and Short (1985) and Huber and Roth (1990) have put forward the dimension of certainty / uncertainty as an orientation in personal decision-making and action. A person with an high tolerance of uncertainty would: seek out situations with an element of risk; be able to judge the nature of the risks involved and be able to minimalize them, being confident in personal professional skills; develop their ideas whilst addressing that situation and be receptive to high-quality ideas from others; be inclined to work co-operatively with others. The interview data suggests that the teachers involved had a high tolerance of uncertainty. They were well-established professional risk-takers as such: it is likely that they would be involved any innovation, whatever its demands, that they saw capable of making a positive contribution to their professional work.

The managers of education systems throughout the world are demanding that school subjects, including science and technology, are both kept up-to-date and made more relevant to broad social, usually economic, goals. They are also reducing the skilled curriculum development and professional development support available to teachers. Teachers' positive responses must involve an increased element of risk-taking. It therefore would be helpful for teachers if ways could be found to help them in: identifying curriculum needs and opportunities; evaluating external pressures for curriculum change; identifying the risks involved in bringing about a given innovation; reducing and addressing those risks. This would seem to present a broad forum for action research and the provision of professional support.

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REFERENCES

Concise Oxford Dictionary (1982). Oxford: Clarendon Press.

Doyle, W., Ponder, G. (1977). The practicality ethic in teacher decision-making. Interchange, 8 (3), 1-12.

Fullan, M. (1991). The new meaning to educational change. London: Cassell.

Gilbert, J. (ed.) (1992). Remote sensing in science education. Hatfield: Association of Science Education.

Gilbert, J. (in press). The interface between science education and technology education. International Journal of Science Education, 14 (5).

Huber, G., Roth, J. (1990). Teachers' classroom activities and certainty / uncertainty orientation. In: C. Day, M. Pope, & P. Denicolo (eds.). Insight into teachers' thinking and practice (pp. 119-32). London: Falmer.

Meeke, N. 1989). The concept of the key technologies. London, Further Education Unit.

Mohlman, G., Coladarci, T., & Gage, N. (1982). Comprehension and attitude as predictors of implementation in teacher training. Journal of Teacher Education, 33 (1), 31-6.

Pacey, A. (1983). The culture of technology. Oxford: Blackwell.

Rudduck, J. (1988). The ownership of a change as a basis of teachers' professional learning. In: J. Calderhead (ed.). Teachers' professional learning. Lewis: Falmer.

Sorrentino, R., Short, J. (1985). Uncertainty orientation, motivation and cognition. In: R. Sorrentino, E. Higgins (eds.). The handbook of motivation and cognition: foundations of social behavior (pp. 379-403). New York: Guildford.

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THE RELUCTANT PRIMARY SCHOOL TEACHER

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ABSTRACT

The study attempts to identify the factors which affect teachers' reluctance to teach science, then explains an approach to help teachers teach science in a worthwhile manner over the school year while monitoring any changes in their confidence and competence. It was found that the confidence and competence of the teachers improved during the year such that they were able to teach successful science lessons on a regular basis.

INTRODUCTION

"Science in Australian primary school is thus in a state of crisis" (Department of Employment & Training, 1989)

It is a sad commentary on the teaching of primary science that the national inquiry into mathematics and science education came to the above conclusion. This report concluded that science was not a priority for many teachers and that many lacked confidence in teaching the subject.

Teachers' lack of confidence in teaching science has been well documented (Symington, 1974; Seddon, 1981; Rennie, Parker & Hutchinson, 1985; Yates & Goodrum, 1990). Few studies have investigated the nature of this lack of confidence and how to improve it in the classroom. This study attempts to do that.

METHODS

Using a concerns-based case study approach, twenty teachers were introduced to a structured science curriculum and their concerns and attitudes were monitored throughout the year as they implemented the program in their classrooms. The primary science program used was an experimental edition of "Science for Life and Living" (Biological Sciences Curriculum Study, 1989a,b,c). This program integrates the areas of Science, Technology and Health and provides a structured approach to the small-group learning of major concepts and skills.

A letter was sent to about fifty primary schools in the northern corridor of Perth, Western Australia, requesting volunteer teachers from Years 2, 5 and 6, who felt reluctant about teaching science. Over one hundred teachers responded, and subsequent telephone conversations with a sub-sample ensured the selection of twenty reluctant science teachers:

- eight Year 6 teachers, four male and four female;
- six Year 5 teachers, all female;
- six Year 2 teachers, all female.

The project began with a one-day inservice activity at the commencement of Term 1 at which teachers' concerns and needs about science were identified. A 3-day in-service program followed one week later when workshops on the planned curriculum and material kits were provided. Additional formal support was given, and formal data collections occurred at half-day inservice sessions at the commencement of Terms 2 and 3. Throughout the four teaching terms there was individual and continual contact with teachers through classroom observations and semi-structured interviews. Teachers maintained journals documenting their experiences.

Teachers recorded their perceptions of their confidence and competence to teach science before, during and at the completion of the year's teaching as well as the reasons for these perceptions. They were asked if they perceived themselves as either lacking confidence, confident or highly confident. A similar three-point scale was used for competency.

To obtain a more objective measure of confidence, the study has utilised some of the strategies outlined in the Concerns Based Adoption Model (CBAM) of Hall and Hord (1987), in particular the strategies for identifying Stages of Concern and Levels of Use with regard to curriculum implementation. As teachers implement an innovation their level of confidence is reflected in the kinds of concerns they raise and the level at which they use the curriculum materials. As teachers gain confidence it is expected that they might move from self-orientated to more student-orientated concerns and from mere mechanical use of the curriculum to a more refined or locally-adapted use.

Teacher concerns and levels of curriculum use were identified by data from interviews, questionnaires and teachers' journal entries and classified into the various stages of concern of the CBAM model. This approach provided us with what we have termed observed levels of confidence as compared with the teachers' perceived confidence levels. Additional information was obtained from specific classroom observations on questioning skills, lesson pace and the degree of implementation of the curriculum's small-group cooperative learning strategy. This provided information on the level of competence of the science teaching.

RESULTS

Year 6 teachers

Background: All the teachers with the exception of Sally (no real names are used) were experienced teachers. Sally had only taught for one year and was trained as a teacher librarian. The majority of teachers were four-year trained with a B.Ed. qualification. Bill was three year trained and Sonja was enrolled in a masters degree. No teacher had majored in science or science education in their preservice degree. All the teachers had studied biology at upper secondary level except Ben who had studied Physics and Chemistry and Bob who had not studied any science beyond lower secondary.

Most timetabled science for an hour per week but suggested this was the first subject to disappear in the week's schedule when other demands were made.

Initial Concerns: From the initial questionnaire the teachers expressed their major needs and concerns as

- A need for clear direction in their science teaching (Barry, Ben, Bob, Sarah, Bill)
- More help with materials (Barry, Ben, Bob, Bill)
- Dissatisfaction with their present science teaching (Barry, Ben, Bob and Sonja)
- A need for more information on suitable topics to be taught (Barry, Sue, Sarah and Sally)

The Year 6 teachers, as a group, tended to feel that they themselves did not lack confidence but rather factors within the school system contributed to their reluctance to teach science. The exceptions to the group feeling were Sally and Barry.

The general feeling was that teaching science involved considerable effort. This effort involved preparing a suitable topic and organising the materials necessary to teach that topic. As well there seemed to be a lack of direction in the area of science. Sarah suggested it was not 'confidence' but rather a question of priorities. The feeling was that many teachers do not consider science to be a high priority and hence were not willing to expend energy in organising for it.

A comparison was made between teaching science and social studies. The teachers suggested social studies was much easier to teach because the curriculum was well organised, the information was all together in one book and there were few materials needed. Science on the other hand required gathering ideas from a variety of books as well as a lot of materials for activities. Many of these materials were consumable and had to be replaced each year. One teacher suggested that there are some teachers who love science and are willing to put in the effort but the majority do not.

Confidence and competency: Although many of the teachers initially indicated that they felt some degree of confidence with teaching science before the project started, their confidence improved during the year. Figure 1 shows the differences in confidence before and late in the project both in terms of their perception of themselves and from the more objective measure of their concerns as explained earlier. Barry and Sally initially expressed a lack of confidence and this was confirmed by the type of concerns they elicited. In Barry's case his confidence grew enormously during the course of the year, with his level of concern moving away from the personal and informational towards management and consequences for learning.

Interestingly, Ben indicated, on the initial questionnaire, that he lacked confidence but his general behaviour and comments suggested he was initially the most confident of the eight teachers. This would indicate that for some people there is a difference between what they write in questionnaires and their actions.

While there were observable differences among the teachers in terms of the quality of their science teaching, all teachers taught science competently and on a reasonably regular basis during the year. During and at the end of the project the teachers were asked what caused the change in their confidence and competency. The two most common reasons given were the use of a structured programme with supporting materials and the positive responses of the students.

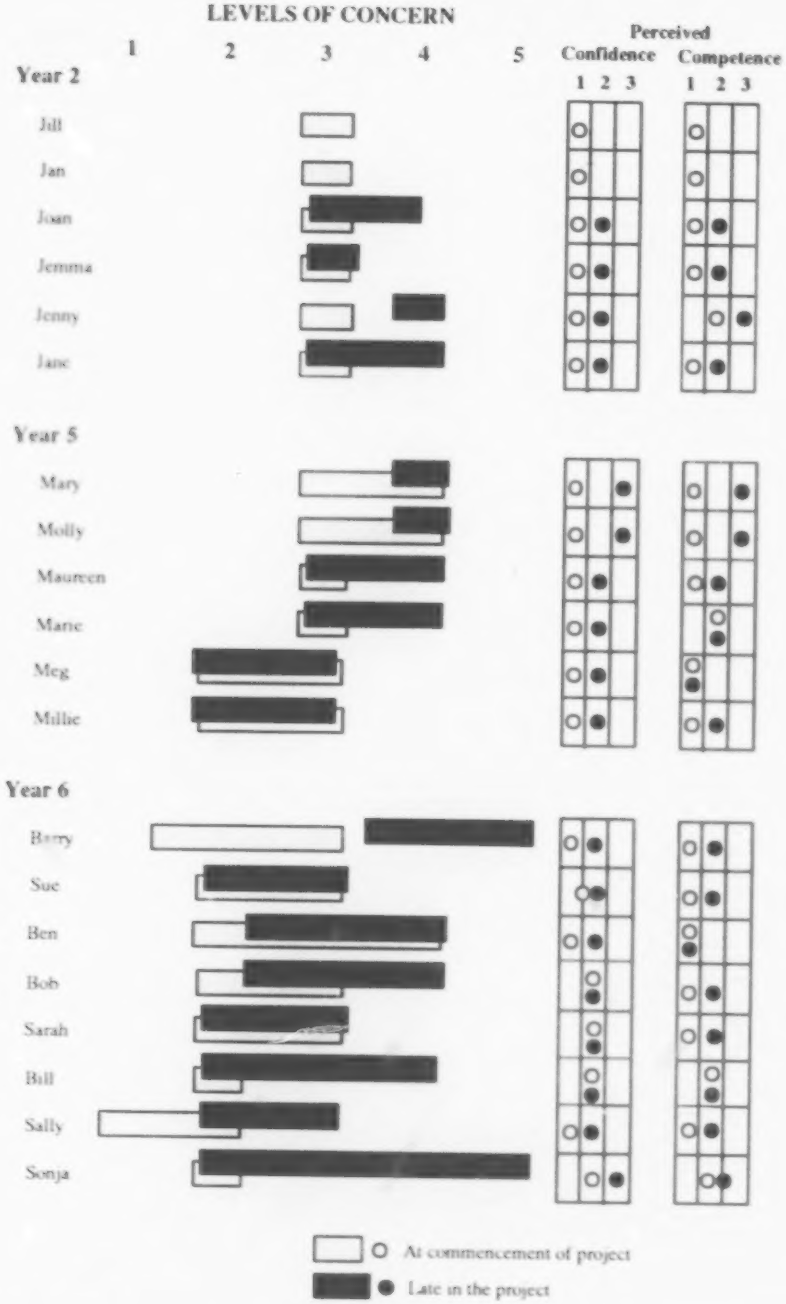

Fig. 1. Changes in observed and perceived confidence levels and perceived competence levels of teachers over the course of the project.

The Levels of Concern correspond to those described by Hall & Hord (1987) as follows: 1: Informational; 2: Personal; 3: Management; 4: Consequences; 5: Collaboration.

Perceived confidence and competence were each ranked by teachers on a 3-point scale as follows:

Confidence: 1 = lacks confidence; 2 = confident; 3 = highly confident.

Competence: 1 = requires attention; 2 = competent; 3 = highly competent.

Some teachers gained enormously both in confidence and competence, as evidenced by changing levels of concern and self-perceptions (Fig. 1). For some teachers improvements in confidence were concomitant with improvements in competence, though for others this was not the case.

Year 5 and Year 2 teachers

Background: These teachers, like the those above were well-experienced general primary teachers, but tended to have fewer post-graduate qualifications and very limited science experience at secondary, tertiary or inservice levels. Mary was an exception, having competed a first year science course at tertiary level. Despite the general lack of science background, all the teachers taught some kind of science weekly. They preferred biological topics, recognising the physical science areas as difficult for them.

Initial concerns: At the start of the project the most common concerns were the lack of structured science curriculum from which to plan weekly lessons, background knowledge in science, and readily-available materials and equipment with which to teach science.

Unlike the year six teachers who tended to voice their concerns in terms of deficiencies in the system, the Years 2 and 5 teachers tended to view their concerns in terms of their own deficiencies, in particular a lack of knowledge about science and how to teach it.

Confidence and competence: At the commencement of the teaching program, all twelve teachers identified themselves as lacking confidence in their ability to teach science (Fig. 1). In the early stages of the program, their concerns were centred at the Management level (level 3) with the most common ones being the management of small groups (a required strategy with this particular curriculum), time constraints and the maintaining of on-task activity. The initial 3-day program was designed to provide for Informational (level 1) and Personal (level 2) concerns, hence only two teachers (both at year five) expressed concerns at this level by the time they had commenced teaching and they related mainly to their feelings of inadequacy concerning their science knowledge.

As with confidence, most of the teachers rated themselves low in perceived competence as science teachers at the commencement of their teaching program.

By the end of the project there were changes in both the perceived levels of confidence and competence and observed levels of confidence (as indicated by changing levels of concern) in the majority of teachers (Fig. 1). With one exception (Meg) all rated themselves as at least "confident" and "competent". Analysis of teachers' concerns supported this apparent improvement in confidence. With two exceptions the teachers' concerns were moving into the Consequences level (level 4), and while Management issues were still a concern (e.g. insufficient time for science, group management) there was a noticeable change in focus towards child response, individual learning differences and child-evaluation. For two Year 5 teachers (Meg and Millie) their perceived inadequate science knowledge remained of paramount concern for them despite gains in confidence.

Teachers in Years 2 and 5 gave similar reasons to Year 6 teachers for changes in their perceived confidence and competence. These were the use of a structured curriculum, the positive responses of the children and the development of a working familiarity with the program.

CONCLUDING COMMENTS

The teachers in this project gave various reasons why they were reluctant to teach science. Some of the reasons were viewed in personal terms while others related to a lack of support for science teaching within the school system. Despite this initial reluctance, the majority of the teachers gained in confidence in teaching science. From the teachers' perspectives, access to a structured program with supporting inservice workshops, equipment and materials was a major reason. The positive responses of the children also contributed.

With regard to background knowledge in science, the program provided sufficient information to meet the needs of the majority of the teachers and to provide a basis for presenting worthwhile lessons. However, two Year 5 teachers (Meg and Millie) continued to express background inadequacies in science at the end of the project, inadequacies which they believed detrimentally affected their competence to teach science. When observing questioning skills during science lessons, the importance of background knowledge was seen in the quality of the questions asked by some teachers and the insights they exhibited in building on children's ideas. (This was particularly evident in the questioning behaviour of Mary, the teacher with some tertiary science.) Such questioning however, does not only require background knowledge but also an understanding of how children think coupled with appropriate questioning skills. (In this regard, Molly, another teacher who achieved a highly confidence level, was able to broaden the context of the children's science through her ability to draw on their home experiences).

There is no doubt that the use of a quality structured program with supporting equipment and appropriate inservicing can help the reluctant primary teacher initiate worthwhile, sequenced science lessons on a regular basis. However, a short-term project such as this has obvious limitations in identifying the strategies for encouraging long-term quality science teaching. As the project drew to a close, while it was obvious that many of the teachers' concerns such as a lack of science background, had been alleviated, others of a more systemic nature remained (such as the inadequate time allotment for science in the school timetable, school support for science as a core subject and the development of competence for curriculum choice and individual action). Follow-up is planned to determine the longer-term success of the project for these teachers.

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REFERENCES

Biological Sciences Curriculum Study (1989a). Science for life and living. Grade 2 teacher's guide Experimental Edition. Dubuque: Kendall Hunt.

Biological Sciences Curriculum Study (1989b). Science for life and living. Grade 5 teacher's guide Experimental Edition. Dubuque: Kendall Hunt.

Biological Sciences Curriculum Study (1989c). Science for life and living. Grade 6 teacher's guide Experimental Edition. Dubuque: Kendall Hunt.

Department of Employment and Training (DEET). (1989). Discipline review of teacher education in mathematics and science. Vol. 1. Canberra: Australian Government Publishing Service.

Hall, G.E. & Hord, S.M. (1987) . Change in schools: Facilitating the process. Albany NY: State University of New York.

Rennie, L.J., Parker, L.H. & Hutchinson, P.E. (1985). The effect of inservice training on teacher attitudes and primary school science classroom climates. Research Report number 12, Department of Education, University of Western Australia.

Seddon, T. (1981). Australian primary school science: A review of surveys of practice. The Australian Science Teachers Journal, 27(1), 37-41.

Symington,D. (1974). Why so little primary science? The Australian Science Teachers Journal, 20(1), 57 - 62.

Yates, S. , & Goodrum, D. (1990). How confident are primary science teachers in teaching science? Research in Science Education, 20, 300-305.

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EXPERT - NOVICE DIFFERENCES IN SCIENCE INVESTIGATION SKILLS

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ABSTRACT

Many school students experience difficulty in conducting science investigations (Hackling & Garnett, 1991; Murphy, 1988). Students in Western Australia have poorly developed skills of problem analysis, planning and carrying out controlled experiments, basing conclusions only on obtained data, and recognising limitations in the methodology of their investigations. This paper compares the work of 10 expert scientists and 10 Year 12 science students as they conducted a laboratory based investigation. The results provide insights into expertise in science investigation skills.

INTRODUCTION

Woolnough and Allsop (1985) have identified three aims that can validly be achieved through laboratory work: the development of process skills and laboratory techniques; getting a feel for phenomena; and being a problem-solving scientist. Several authors have argued that scientific problem-solving skills can be developed through inquiry oriented or investigation style laboratory work that gives students opportunities to practise the skills of problem analysis and planning experiments, collecting data, and organising and interpreting data (Tamir & Lunetta, 1981; Woolnough & Allsop, 1985; Tamir 1989).

Experts bring extensive domain specific schema knowledge to problem-solving tasks which enables them to generate high quality problem representations which guide the selection of efficient solution processes (Chi, Feltovich & Glaser, 1981). Experts spend more time on problem analysis (Larkin, 1979), do more high level metaplanning (Hayes-Roth & Hayes-Roth, 1979), and demonstrate greater metacognitive control over processing than novices (Schoenfeld, 1986). The comparison of the performance of experts and novices has been fruitful in characterising the nature of expertise and devising instructional interventions that can efficiently develop expertise in novice subjects (Hackling, 1990; Larkin, 1979).

This paper reports on a study which compares the performance of Year 12 science students and expert scientists as they work on a science investigation.

RESEARCH QUESTIONS

1. Which process skills are applied in the problem analysis and planning, data collection, data interpretation and concluding phases of a laboratory investigation by Year 12 science students and expert scientists?

2. What features appear to characterise expertise on a laboratory-based problem-solving task?

METHOD

Subjects

The Year 12 students were from the top half of the population in terms of science achievement and the sample comprised two students from each of five different schools, equal numbers of males and females and equal numbers of students studying either biological or physical sciences. Similarly the sample of experts comprised equal numbers of males and females and equal numbers working in the biological and physical sciences. The experts all had doctoral study and extensive research experience in science.

Procedure

The open-ended, problem-solving task was administered to subjects individually. The task was set in the context of building bridges and involved an investigation of the factors influencing the bending of beams under load. The task is fully described in Hackling and Garnett (1991). Subjects worked on the task with concurrent verbalisation (Ericsson & Simon, 1980). Subjects' verbalisations and apparatus manipulations were recorded on videotape. A coding manual guided the dual and independent coding of the videotapes by two trained coders.

RESULTS

Results are presented in terms of the process skills displayed by subjects during the four phases of the investigation: (1) analysis of the problem and planning, (2) collecting information, (3) organising and interpreting information, and (4) concluding.

(1) Analysis of the Problem and Planning

The most distinct feature of the experts' problem solving was the long period of time devoted to problem analysis and planning. Experts' problem analysis and planning typically commenced with the identification of a number of potential independent variables and then the generation of research questions or hypotheses. This was often followed with metaplanning which involved devising an overall strategy for the investigation which includes the number, types and sequence of experiments to be conducted. Several experts conducted small trials with the apparatus to determine appropriate ranges and intervals of measurement, the development of a measuring technique and planning for repeat measures and data recording. The Year 12 students spent only a few minutes on problem analysis and planning. None of the students did any metaplanning or verbalised an intention to control variables while planning their investigations in marked contrast to the work of the experts. The students only identified an average of 1.6 potential independent variables for investigation compared to 5.1 for the experts. These data are presented in Table 1.

TABLE 1
BEHAVIOURS ASSOCIATED WITH ANALYSIS OF THE PROBLEM AND PLANNING

Behaviours	Group	
	Year 12 (n = 10)	Experts (n = 10)
Mean number of potential independent variables identified during problem analysis	1.6	5.1
Generated research questions or hypotheses for investigation	1	5
Planned how a variable would be applied or measured in an experiment	6	9
Verbalised an intention to control variables	0	7
Planned data recording	2	6
Planned an overall approach to the investigation (metaplanning)	0	5

(2) Collecting Information

All experts made careful measurements of bending, the dependent variable. They all took great care to ensure the accuracy of their measurements. Most established that they could estimate to half of one millimetre, many went to extraordinary lengths to minimise parallax error and all of the experts repeated measurements, some conducting three replicates of all measures. The experts chose to use both a wide range and narrow intervals of measurement and therefore collected far more data than the students. Experts were absolutely systematic in their control of variables; they standardised their measurement procedures and controlled variables when comparing different beams. The experts were also highly metacognitive while performing their measurement routines. They anticipated results, monitored results as they were obtained, reflected on the consistency of results and if not satisfied would then go back and repeat the measurements.

Only six of the students measured the dependent variable. Those that measured bending took care with parallax error and standardised their measurement procedures. These six students on average made 4.2 measurements for each variable tested compared with 8.4 for the experts. Only one of the students repeated any measurement. A major weakness in the work of the students was failure to control variables when changing beams to test the effect of beam thickness, cross-sectional shape or material. These data are presented in Table 2.

TABLE 2
BEHAVIOURS ASSOCIATED WITH COLLECTING INFORMATION

Behaviours	Group	
	Year 12 (n = 10)	Experts (n = 10)
Mean number of experiments performed	3.3	3.3
Measured changes in the dependent variable	6	10
Mean number of measurements for each variable tested	4.2	8.4
Repeated measurements	1/6[a]	10/10
Measured zero values for dependent variable	6/6	10/10
Avoided parallax errors with measurements	6/6	10/10
Measurements made at the point of maximum deflection of the beam	5/6	10/10
Controlled variables by standardising measurement procedures	6/6	10/10
Controlled variables when changing beams	5	10

Note. [a] One of the six students who made measurements, repeated some of the measurements.

(3) Organising and Interpreting Information

The experts were quite exhaustive in recording all details of the way in which their experiments were conducted with some attention being payed to making the records clear and neat. Concerns were expressed that enough information had to be recorded so that other researchers could replicate their experiments and that the records should be clear so that if they worked on the problem again in the future they would be able to work out what they had done previously. All numerical data were recorded in tabular form with units and column headings. All of the experts constructed line graphs from their data and used them to evaluate the consistency of the data and the nature of the relationship between the variables plotted. Many of the experts added error bars to the plotted points and used these as a guide to drawing a line of best fit and determining if the relationship was linear or not. Most of the experts were careful to place limits on the generalizability of their conclusions.

Two of the students did not record any data and only one student plotted a graph. The main weakness in students' data interpretations was that half of them made comparisons between the bending of beams that differed in terms of more than one variable, that is, they made uncontrolled data interpretations. These data are presented in Table 3.

TABLE 3
BEHAVIOURS ASSOCIATED WITH
ORGANISING AND INTERPRETING INFORMATION

Behaviours	Group	
	Year 12 (n = 10)	Experts (n = 10)
Number of subjects who recorded data	8	10
in tabular form	6/8[a]	10/10
with units	6/8	10/10
with column headings	5/8	10/10
Number of subjects who transformed data into a		
restructured table	2	2
graph	1	8
Number of subjects who made uncontrolled data interpretations	5	0

Note. [a] Six of the eight students who recorded data did so in a tabular form.

TABLE 4
BEHAVIOURS ASSOCIATED WITH CONCLUDING

Behaviours	Group	
	Year 12 (n = 10)	Experts (n = 10)
Mean number of valid factors identified [a]	2.5	3.3
Number who went beyond their data in drawing conclusions	1	1
Number who recognised methodological limitations of their investigation	5	10

Note. [a] These are the factors influencing beam bending that were identified and experimentally validated.

(4) Concluding

Once experimental work was completed the subjects summarised their findings. Throughout their work the experts demonstrated an awareness of methodological limitations of their investigation. In their planning experts stated many assumptions about in-built errors (e.g. the string has no mass), when concluding they identified limitations (e.g. insufficient replication) and interfering variables (e.g. the length of beam extending beyond the retort stand). The students demonstrated little awareness of the methodological weaknesses of their experiments. These data are presented in Table 4.

DISCUSSION

The subjects were confronted with a novel problem-solving task set in a real-world context. Expert problem solvers analyse problems and identify cues that activate relevant knowledge schemas to create a mental representation of the task that can facilitate the planning of appropriate solution processes (Chi et al., 1981). Previous studies of problem solving in science and social science indicate that extended periods of problem analysis and solution planning ultimately lead to efficient problem solutions (Larkin, 1979; Voss, Tyler & Yengo, 1983). The most notable feature of the students' work was their lack of problem analysis and planning before commencing on data collection procedures. Very few students planned how they would apply or measure variables or record data before they commenced data collection procedures. There was no high level up-front metaplanning (Hayes-Roth & Hayes-Roth, 1979) of an overall approach to the problem. In fact most planning was low level, task specific planning in response to circumstances that arose during experimental work, typical of that revealed by previous research into adolescents' planning (Lawrence, Dodds & Volet, 1983). Many students demonstrated a lack of metacognitive control over processing (Schoenfeld, 1986). One Year 12 student performed the same repetitive measurement routine for 25 minutes without any overt monitoring or reflection on the usefulness of the process he was performing.

The students appeared to lack a well-developed schema for the structure of a controlled experiment. Only four students used the term hypothesis and no student used any of the terms variable, independent variable, dependent variable, control of variables or replication while working on the problem. None of the students verbalised an intention to control variables. Millar and Driver (1987), and Rowell and Dawson (1989) would argue that reasoning skills such as control of variables are developed in particular contexts and are difficult to abstract and generalise to the level where they can be applied easily to novel tasks in unfamiliar domains. Many Year 12 students did however control variables at the level of being systematic in measurement procedures of which they would have had extensive experience.

The Year 12 students used effective measurement procedures taking care with zero values and parallax error. The high school students relative success on the data collection phase of the investigation versus the planning and analysis phase is likely to be a reflection of the style of laboratory work to which students have been exposed. Analyses of the implemented curriculum in the USA (Tamir & Lunetta, 1981), Israel (Friedler & Tamir, 1984) and Australia (Tobin, 1986) indicate that most high school practical work involves recipe style exercises that are at the lowest level of openness to student planning (Tamir, 1989). Such exercises give students much practice in data collection procedures but no opportunity to practise problem analysis and planning.

The concluding phase of the investigation revealed an additional weakness in the students' understanding of experimentation. Very few students could identify limitations in their experimental procedures which suggests that they were unaware of the numerous interfering variables that influenced their experimental findings. It is likely that these students would place unwarranted confidence in their conclusions.

CONCLUSIONS

The features that most strongly characterised expertise on this investigation task were: (1) extensive problem analysis, planning a general approach to the investigation and thorough planning of each experiment; (2) the use of trials to develop an accurate and reliable measurement technique, and establish suitable ranges and intervals for measurement; (3) replication and repeated measurements; (4) thorough control of variables; (5) active metacognitive control over data gathering procedures; (6) exhaustive data recording, the construction of graphs to check the consistency of data and identify the relationship between the variables plotted; (7) cautious data interpretation and generalisation; and (8) awareness of the methodological limitations of their experiments.

The Year 12 students' success on the problem-solving task was limited by ineffective problem analysis, planning, and control of variables.

If high school students are to develop a comprehensive repertoire of science investigation skills there is a need to modify the implemented curriculum to include more investigation style laboratory activities through which students can have the opportunity to practise the skills of problem analysis and planning controlled experiments. There is also a need to explicitly teach the conceptual knowledge regarding the structure of controlled experiments, particularly the concepts of hypothesis, independent, dependent and controlled variables.

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REFERENCES

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorisation and representation of physics problems by experts and novices. Cognitive Science, 5, 121-152.

Ericsson, K. A., & Simon, H. A. (1980). Verbal reports as data. Psychological Review, 87, 215-251.

Friedler, Y., & Tamir, P. (1984). Teaching and learning in high school laboratory classes in Israel. Research in Science Education, 14, 89-96.

Hackling, M. W. (1990). The development of expertise in genetic pedigree problem solving. Unpublished doctoral thesis, Murdoch University, Perth, Western Australia.

Hackling, M. W., & Garnett, P. J. (1991). Primary and secondary school students' attainment of science investigation skills. Research in Science Education, 21, 161-170.

BEST COPY AVAILABLE

Hayes-Roth, B., & Hayes-Roth, F. (1979). A cognitive model of planning. Cognitive Science, 3, 275-310.

Larkin, J. H. (1979). Processing information for effective problem solving. Engineering Education, 70, 285-288.

Lawrence, J. A., Dodds, A. E., & Volet, S. E. (1983). An afternoon off: A comparison of adults' and adolescents' planning activities. Paper presented at the annual conference of the Australian Association for Research in Education, Canberra.

Millar, R., & Driver, R. (1987). Beyond processes. Studies in Science Education, 14, 33-62.

Murphy, P. (1988). Insights into pupils' responses to practical investigations from the APU. Physics Education, 23, 330-336.

Rowell, J. A., & Dawson, C. J. (1989). Towards an integrated theory and practice for science teaching. Studies in Science Education, 16, 47-73.

Schoenfeld, A. H. (1986). What's all the fuss about metacognition? Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Tamir, P. (1989). Training teachers to teach effectively in the laboratory. Science Education, 73, 59-69.

Tamir, P., & Lunetta, V. N. (1981). Inquiry-related tasks in high school laboratory handbooks. Science Education, 65, 477-484.

Tobin, K. (1986). Secondary science laboratory activities. European Journal of Science Education, 8, 199-211.

Voss, J. F., Tyler, S. W., & Yengo, L. A. (1983). Individual differences in the solving of social science problems. In R. F. Dillon & R. R. Schmeck (eds). Individual differences in cognition. New York, Academic Press.

Woolnough, B., & Allsop, T. (1985). Practical work in science. Cambridge: Cambridge University Press.

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ADULT EXPERIENCES OF SCIENCE AND TECHNOLOGY IN EVERYDAY LIFE: SOME EDUCATIONAL IMPLICATIONS

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ABSTRACT

This paper outlines a project that is focussed on examining the complex ways in which adults experience science and technology in different areas of their everyday life including paid work, the home, health and leisure. The research has involved interviews with individual adults situated in a diverse range of life situations in New Zealand. A case study is presented to indicate the type of data being analysed and the implications emerging for education from the project.

INTRODUCTION

Research that has focussed on the levels of scientific knowledge of the public has typically resulted in wide media reportage and pronouncements about the serious nature of the levels of ignorance displayed. Maybe the best known project of this nature is that of Durant et al in the UK (1989), and there has been similar work led by Millar in the US (National Science Board, 1988). Surveys in Australia and New Zealand have demonstrated that much of the public has limited understanding and knowledge, and ambivalent attitudes to science and technology (Eckersley, 1988; Burns, 1990; Department of Industry, Technology and Commerce, 1991).

Much of the recent research on the relationship of the public to science and technology must be critically scrutinised, for there has been a tendency to rely on large scale surveys as the favoured methodology. More seriously, much of the research has made grossly simplified assumptions about the nature of science and technology, and has not considered how adults and children obtain scientific and technological knowledge and utilise it in everyday life. According to Birke(1990), the public has been portrayed as "inevitably deficient".

It is reassuring that there is a growing critique of the simplified methodologies, assumptions and frameworks used in the past few years in much of this research.
Some research currently being undertaken in England on science and the public includes projects that are breaking new ground, and these include some that are qualitative and small scale in nature. A useful overview of this research has been provided by Ziman (1991), and he presents some stimulating insights into where this research is heading in terms of its challenge to earlier assumptions. He notes that

> a simple "deficit" model, which tries to interpret the situation solely in terms of public ignorance or scientific illiteracy, does not provide an adequate analytical framework for many of the results of our research (p.101).

Researchers who are examining science and technology in adult, complex situations are at the beginnings of a major advance in development of theoretical frameworks. These advances seem to parallel those of a decade or so ago when science educators began to explore what we have come to refer to as children's science.

THE FOCUS OF THE PROJECT

Critiques of existing research and recent theoretical developments have informed the development of the research reported here. The project has been based on a number of assumptions, viz.

- technology permeates our lives to such an extent that we can talk of a "technological texture to life" (Ihde, cited in Ferre (1988, p.9), or as Wenk (1986, p.6) suggests "we not only live with technology, we live technology";
- ambivalence, inconsistency and contradiction are a common feature of individuals' attitudes to science and technology;
- technology and science are not experienced as monolithic by individuals; attitudes to science and technology are a very restricted aspect of the total experience of individuals in these realms;
- research should not adopt an uncritical understanding of science and technology otherwise there will be a tendency to demonstrate deficit public understandings;
- there is a need for exploratory research that captures some of the complexities of adult life experiences of science and technology; and
- such research will help guide our understandings of science and technology, and will have implications for the education of adults and children.

The project commenced in 1991, and became known as the RETEL (Research into the Experience of Technology in Everyday Life) Project. While analysis of research data is still at a preliminary stage, it is possible to report the methodological approach utilised and some initial analysis in the form of a case study, and to draw out some implications for science and technology education.

Aims

The basic aim of the RETEL project is to investigate the knowledge, understandings, valuing, attitudes, feelings and skills of adults in their everyday experiences of technology and science. The project aims to explore the extent to which individuals define experiences as technological/scientific experiences; the extent to which they are aware of the pervasiveness of technology in their lives; the linkages between individual experiences of technology/science and how these linkages might relate to an individual's generalised conceptions of technology and science; and the implications of the findings for technology and science education.

As educators of science and technology we assume and hope that our endeavours will have a lasting impact on our students, not only in their careers, but more generally in their everyday lives. But we know very little about the long term outcomes. Further, as Jenkins (1990, p.49) notes, in developing the school science curriculum we confront a major problem because "so little is known about the needs of students and adults for scientific knowledge". And we know very little about the ways this knowledge is constructed and utilised in adults' everyday life. It is an important aim of this project to throw some light on these questions.

Method

A diverse group of sixteen individuals is being selected for interviewing on the basis of preliminary information about their occupations, life situation, age, gender, ethnicity, social class. Equal numbers of males and females are being chosen. Eight individuals in

New Zealand have been interviewed during 1991 and 1992; and the remainder will be chosen and interviewed in Australia.

An interview schedule is structured to collect background data on the subject; explore an individual's experiences in an aspect of housework, paid work/unemployment, health, and leisure or transport (with the particular aspect in each area nominated by the subject as having major significance for them); explore a subject's generalised conceptions of technology, science and their inter-relationship: ask subjects whether they perceive technology/science in each of the aspects of their everyday life previously discussed: and finally, allow free-ranging discussion of my perceptions of inconsistencies and uncertainties during the interview. As the interview proceeds, then, there is a gradual shift in my stance from that of a naive listener to a challenger of subjects' positions.

CENTRAL THEMES: A CASE STUDY

There are two major themes emerging from the interview data analysis: a. the contexts in which knowledge of technology and science is constructed and utilised in everyday life situations, and b. the subject's generalised conceptions of technology and science and how these relate to specific conceptions of these areas in particular everyday situations.

To share initial insights into these two aspects of the RETEL project, we turn to a case study of one subject, George Lane (a pseudonym), who is a 33 year old dairy farmer in the Waikato District of New Zealand. George grew up on a dairy farm, and completed high school and a diploma in architectural drafting (but has never practised). George has spent virtually all of his adult life in dairy farming, and the farm that he owns has 300 cows. He employs some labour, is married and has a baby daughter.

The Contexts of Everyday Knowledge of Technology and Science

In the construction and use of everyday knowledge we can identify: key factors that constitute the context, motivations for seeking knowledge, sources of knowledge, and the breadth and depth of the knowledge constructed.

* Key factors that constitute the context

An overarching factor in the context in which George works is the economic one. He notes that

> We're on touch and go. If this situation stays for say three years we'd be a marginal farm . . . .In the situation we are in, in the spring, I can make a decision that will consequently affect my season's production. It could very easily knock anything up to thirty/forty thousand dollars off my income.

George recounts "one of the hardest lessons that I've ever learned" when a decision he made about grazing his cows one year resulted in such a loss. He says people are not aware of this "management side" to farming and how mistakes cannot readily be rectified.

George's network of social relationships is a wide one, and it is crucial in providing him with many knowledge resources that relate to his farming activity, and this is discussed further below. One important aspect of the social context identified by George is his family: for example, the pregnancy of his wife and the recent birth of his daughter quite clearly have affected the way that he now treats his knowledge about poison sprays. This reminds us that contexts are dynamic: that as they change so will the need, and perceived need for knowledge change. Further, existing knowledge that has been constructed may well be reconceptualized.

* Motivations for seeking knowledge

Economic aspects of the context both allow and demand of George to seek knowledge. His position in the economic structure as an owner-farmer gives him a significant level of control over his production activities, but for economic viability and success there are pressures. This is clearly why George says "I don't think you can ever stop learning" and that "you have got to be open to suggestions all the time because just the slightest little difference".

Another significant factor in George's motivation to seek knowledge about farming is his admitted fascination with technological innovation and artefacts-and this marked interest is not simply driven by economic concerns, as we will see later.

* Sources of knowledge

One is struck by the great range of sources from which George seeks and obtains knowledge about his everyday practices on the farm. These sources include past farming experiences, his dairy farming brother (" the guru of growing grass"), a veterinary friend, dairy companies who provide daily production reports, a consultant from the Ministry of Agriculture (for whose advice he pays $4000 per annum), Field Days, conferences, open days, other farmers, the mass media and controlled experimentation on his farm. There is clearly great complexity in the ways which George will make sense of information and develop understandings from these sources which may well be conflicting.

* Breadth and depth of the knowledge constructed

The breadth and depth of knowledge is a vital question for the individual in everyday life situations. In George's case there is obvious awareness on his part about many aspects of the ways he seeks out and selects knowledge. He comments:

> I feel myself that the way I operate here . . . .that I shouldn't get too involved in any one aspect of it rather than have a basic knowledge of a lot of it. Because . . . the whole reason why I am here is that if I can't make a profit at the end of the day, I am not going to be here much longer. So what I'd like to do is to know as much as I need to know to be effective in that area. . . . But why the hell know more if I can get by with knowing that much and still do a good job?. . . . I think with the wide variety of things I have got to know . . .I've got to be a horticulturalist, I've got to be a veterinarian, I've got to be a mechanic and I've also got to be a businessman. Now if I try to do all four of those skills very well, I am not going to make the grade.

The complexity of the context in which he works clearly places demands on George that must limit the time he has to construct detailed knowledge in some areas. For example, George recounts his selection of knowledge from his veterinary friend:

> he'll ... start talking about a reason for this happening. Now I will take the information I want from ... I'll let him talk... I'll ask basic questions to find out, OK, how I can improve that and that but he'll tell me ... why it's happening and how it's happening and everything. I'll extract the information I need to rectify it and that's it. As far as the rest of it goes I don't want to know about it.

In referring to the central activity of growing grass, George states that, it is not really necessary for him to know the details of the biochemistry involved. Further, he can depend on another's detailed knowledge:

> what I go and look for is I want to grow a plant, that nice, beautiful, healthy plant . Now I basically know how to do it as far as what I put on that to make that grow like that. Now I don't know the chemistry attached to growing that.... I suppose I should know ... but to me I don't think I should know. . . .Well, I should know in the sense that it could be valuable and if it doesn't grow I could then do it myself. I suppose I am lucky I've got a guy who's had forty years of experience of growing grass. Now I've got his information I can tap into.

Here we see a distinction being made between different types of knowledge: it is not simply a case of knowing more or less. George is content with "knowing how" and is not as concerned with "knowing why", but does recognise its potential value.

Generalised Conceptions of Technology and Science

We now examine general conceptions of and feelings about technology and science held by George and their links to his everyday experience in specific situations .

Technology in general is seen in a very positive light by George. He thinks that:

> It's exciting ... I think it is good in the sense that it is an advancement. Continually advancing which I think is necessary. . . .To me technology is like the science of trying to make everything better.

His enthusiasm is buoyed up by frequent visits to places that involve technological innovation and he is intrigued by the inventiveness involved in technology:

> I love going to places and finding out new little bits and pieces, how people have thought out different ways of doing things different . . . .like field days. . . in the back of my mind when I see something like that, I think well, some brainy bugger's done that. Now someone's sat down and thought that out. How clever he must be . . . .

He is also motivated to be interested because of the potential innovations have for his life. But it is interesting to note that when asked "How much technology do you think you use in your life?" he did not immediately recognise its pervasiveness:

> I suppose we use a fair bit. Like bits and pieces. Like yeah, I suppose we do . . . like I'm forever trying . . . we're forever trying different things to improve other things, you know what I mean? Like using the technology available to improve what we've already got. I think yeah, no, we use it a bit, yeah.

The initial comments made by George concerning science are stereotypical ones, and their negativity contrasts sharply with his general valuing of technology. He speaks of " a whole lot of mad scientists. . .Like people looking down test tubes and figuring things out." He sees them as very narrow, preoccupied with little facts and experiments. But on reflection he has a somewhat more positive image of science recognising that scientists have "developed new products for the dairy industry".

As has been found for some other project subjects, science is identified by George with one of the sciences:

> when you say science I think of chemistry. That's the first thing I think of and then I think, "Oh no, you have got your physics and your biology so" and that type of thing. But that's the first thing. As soon as you say science, I think of chemistry.

His negative feelings about science, it appears, are largely an outcome of school science: George notes that he "hated it as a subject at school and that's stayed ..." These negative conceptions and feelings about science are continuing to have important impacts on George's behavior and his openness to scientific knowledge. He comments on field day visits:

> You can go down and look at soil samples and that type of thing. [But] I'll walk straight past that. OK. That's one thing that I should look at because it is directly in relation to [my farm]. I feel that the information they are going to give me is above what I can understand. That would be my biggest fear. . . .I wouldn't want to go along there and get something thrown at me and then walk away and sort of think that I couldn't understand.

And this fear emerged in school science, for as George notes "as far as the chemical side and that type of thing, no, I just couldn't understand it".

Everyday knowledge and generalised conceptions of technology and science

We have only begun to explore the relationships that exist between generalised conceptions of technology and science and particular knowledge that has been constructed in specific, concrete situations. But for George we can provide some glimpses of the complex emerging picture.

George recognises that he is dependent on technology "for the improvement of our operations. I think it's all very important for everything you do . . . ." Given what we have seen are George's quite restricted conceptions of science, it is not surprising that he is less certain about the relation of science to his everyday operations.

> I think I should ... [when it's] all said and done I use it a lot more than I actually give credit for it. Like I'll use the science of chemicals to try and grow grass, I also use the biological side of it to make my cows health very good. Which are two very important things on my farm and yet I don't like to get involved in it.

Very significantly George has some very fixed notions of where science and where technology is located in his farm life. These emerge from his deeply held distinction between these areas. For instance, George was insistent that fertilisers are not technology but science, because fertilisers evoke ideas about "pHs, nitrogens" and this is chemistry, a central aspect of science. We might consider that in growing grass there is a great deal of technology, but again this is not George's conception. He emphasises that it is "more as science of growing grass"

A most interesting set of distinctions is made by George while explaining the workings of his motorbike. He sees the technology in the motorbike as "just the mechanics of it, just the workings of it. . . .To me science is in the combustion part of it, then everything else around it is technology." Combustion involves two products being mixed to create an explosion and "to me that's science". Braking for George is clearly technology because it involves mechanics. Such distinctions might surprise us, but there is much consistency in George's position that tends to equate anything to do with chemistry (and biology) with science, and physics with technology. School science appears to have left its impact.

Behaviors, Contexts and Everyday Knowledge

From the analysis of data, it is possible to develop a typology that helps us understand how patterns of behaviors, contexts and everyday knowledge are interrelated, and these typologies draw together threads of the previous analysis. In particular the typology helps us understand how knowledge comes to be utilised. Four types have been identified for George, and these can be referred to in terms of his behavior which is marked by Constraint, Experimentation, Uncertainty, and Ambivalence.

* Constraint

In this type a major element of constraint comes from the context; not only will knowledge be constructed within significant contextual constraints, but constructed knowledge cannot be utilised in the way most desired by the individual.

Part of his legal context is governmental regulation of weed growth: if George does not control noxious weeds he is liable to prosecution. George complies by using weed sprays, but he is far from happy about this because he has knowledge of the sprays' constituents and the possibility "they could make you sterile or that type of thing". Recent changes in his family situation have altered the context in which spraying occurs and have increased his sensitivity to what is happening. His wife has had a baby: as a result George has been "enlightened to those type of things that are happening. And it scares me". Clearly we can see tensions between the context, George's behavior and his existing knowledge.

* Experimentation

Experimentation occurs his relatively free economic context and involves active use of existing knowledge and a seeking for additional knowledge. For George, economic factors do loom large. George's ownership of the farm allows him to experiment, but the economic context also prompt these attempts to lift productivity.

In one instance, George has knowledge about overseas practices in dairy farming and is convinced that there may be merit in these for him. Openness to new ideas is an approach that George claims for himself, and this is evidenced by his willingness to give a radically new approach a trial. He has reduced his cow numbers "which some people say is crazy ". As a result of the experiment he has increased production while saving costs in a number of areas. Through experimentation he has constructed knowledge that the new approach "works", and in this case there is a congruity between knowledge, context, and behavior.

* Uncertainty

Behavior marked by uncertainty occurs when the effects of a technological artefact are not considered to be known with confidence, but typically factors in the context support the continuing use of the artefact. A nice case of such a context revolves around George's relationship to the home microwave oven.

Five years ago when he began to use the microwave he reports that "I wasn't too sure about it" having been warned he was "just nuking food". In spite of this comment he persisted with its usage, values it highly for its convenience, and admits he has become dependent on this artefact. Indeed the arrival of the baby in the family has made him learn more about it "because we're trying to get food faster and quicker". However, many uncertainties linger, and he says that he is sometimes "a bit nervous about it . . . because you might put your hand in there and you will feel the waves whistling around". When George is asked about his understandings of the science involved in the microwave oven he is unsure, stating that he does not fully "understand the principles of how it actually does it". But according to George this ignorance does not matter, because he can rely on the knowledge of a mechanical engineer friend who he regards as "a health freak" and goes into "things too deeply". His friend "loves" his microwave, so it must not be dangerous. Questions arise as to whether George might be more certain about the use of the microwave oven if he too had constructed understandings for himself more "deeply".

* Ambivalence.

An ambivalent context is one where technology has insinuated itself - but also been chosen - in an individual's life, and where the individual has both conceptions and feelings about the technology which are unstable

Before he purchased a motorbike four years ago, George happily "used to walk everywhere" over his farm. George now values highly the motorbike for reducing work time. But he is now dependent on it and this dependency "gets worse". It has got to the point where when "you know it is there you tend to get on it and do these things before you actually stop and think ..." Then its usage is often seen by George as uneconomic. We can see here then that a technological artefact purchased to increase productivity has had unforseen consequences which are known and are viewed negatively. But in spite of his knowledge this technology is not within the total control of George: as he says"[the] more you use it the more and more you just tend to do those things". In this complex of relationships between context, knowledge and behaviors, interesting questions are prompted about "rational" behavior and the relative influence of knowledge about technology on that behavior.

CONCLUSION AND IMPLICATIONS FOR EDUCATION

It is not possible from this single case study of a male dairy farmer to draw generalisable conclusions, but it is possible to point to an emerging framework of concepts and questions which can be used to analyse everyday experiences of science and technology. We can also begin to see how these might impinge on our work in education. While some of the ideas and implications may not be new ones for science educators, they may well reinforce principles of effective teaching and learning that have been advocated from different starting points. The following appear to be significant findings arising in the study reported here:

- Everyday technological and scientific knowledge is constructed by individuals in dynamic contexts, economic and social elements being critical elements.
- Individuals have multiple sources from which to construct technological and scientific knowledge and there is a real potential for conflict in this knowledge that will require evaluation and some form of resolution by the individual.
- The breadth and depth of scientific/technological knowledge of the individual is influenced by the context in which the knowledge is constructed and to be utilised. Many factors influence the individual's motivations to seek and select knowledge.
- Individuals' generalised conceptions of technology and science include distinctions that affect their everyday life.
- Experiences of school science can have a lasting impact on adult conceptions and feelings associated with science and technology.
- It is likely that the relationship between generalised conceptions of technology and science and their recognition in everyday activities is highly complex and varied.
- There is a complex interaction between everyday knowledge of technology and science, contexts and individual behaviors. For the individual the inter-relationships are frequently shifting.

I suggest that such findings support education in science and technology that:

- emphasises the changing social, economic, political contexts in which they occur;
- assists students to distinguish, but also to relate, science and technology;
- relates science and technology to the everyday lives of students in a critical and reflective manner;
- assists students to evaluate the worth of knowledge of different kinds and from different sources;
- recognises that feelings, values and constraints of a context will always affect the student's and adult's construction of knowledge and that this is not necessarily irrational; and* is concerned with developing self-esteem for all students in science and technology.

It is obvious from the interviews completed that there are also implications for the education of adults. I have been struck by the marked interest shown by the subjects in the project: a number wanted to prolong the lengthy interviews. It appears that the interviews allow subjects to explore their ambivalence, uncertainty, and constraint in their experiencies of technology and science. This suggests that maybe we should give consideration to the provision of educational forums in which adults could work through these experiences . This might then help adults develop more effective control over their scientifically and technologically textured lives.

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REFERENCES

Birke, L. (1990). Selling science to the public. New Scientist, 127 (1730), 40-44.

Burns, J. (1990). Public attitudes towards and understanding of science and technology in New Zealand: Implications relating to women. Report to the Ministry of Research, Science and Technology. Wellington.

Department of Industry, Technology and Commerce. (1991). An evaluation of the attitudes of Australians to science and technology. Conducted for the Science and Technology Awareness Programme, DITAC.

Durant, J. R., Evans, G.A. and Thomas, G.P. (1989). The public understanding of science. Nature, 340, 11 - 14.

Eckersley, R. (1988). Australian attitudes to science and technology and the future. A report for the Commission for the Future. Canberra: A.G.P.S.

Ferre, F. (1988). Philosophy of technology. Englewood Cliffs, New Jersey: Prentice Hall.

Jenkins, E. (1990). Scientific literacy and school science education. School Science Review, 71(256), 43-51.

National Science Board, (1988). Science and engineering indicators - 1987. Washington, D.C.: Government Printing Office.

Wenk, E. Jr. (1986). Tradeoffs: Imperatives of choice in a high-technology world. Baltimore: John Hopkins University Press.

Ziman, J. (1991). Public understanding of science. Science, technology and human values, 16(1), 99-105.

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IMPROVING THE QUALITY OF PRIMARY SCIENCE TEACHING THROUGH A PRE-SERVICE COURSE

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ABSTRACT

This paper describes a study involving second and third year primary Diploma of Teaching students. It considers their discipline competence, their confidence in teaching particular topic areas and their views of the nature of science teaching in the classes in which they were placed during teaching rounds. It then describes attempts made within the science curriculum course to overcome particular problems.

INTRODUCTION

Science Curriculum staff at Ballarat University College are greatly concerned with the quality and quantity of science teaching carried out in primary schools. Observations over several years have led to the view that science is often poorly taught in almost ad hoc situations, that many primary schools do not have coherent and sequentially developed science programs, and that sometimes the process approach seems to be misused in that children discovering and being busy is seen to compensate for a lack of background scientific knowledge of the teacher.

Our perceptions are not unique. A survey in England in 1978 concluded that few primary schools had effective programs for the teaching of science, and that teachers lacked a working knowledge of elementary science. This resulted in some teachers being so short of confidence in their own ability that they made no attempt to include science in the curriculum. (Department of Education and Science, 1978, p.62). The report of the Discipline Review of Teacher Education in Mathematics and Science (Speedy et al., 1989) suggested ways of improving the science discipline competence of primary teachers.

Several factors are commonly seen to be indicators of the poor health of primary science education. They are:

- lack of understanding of basic scientific principles by teachers;
- lack of confidence in teaching science;
- time considerations;
- lack of resources;
- insufficient significance given to science in the curriculum;
- a lack of understanding and consideration of the aims of science education.

The research was designed to check the validity of these views of primary science education in the Ballarat region, to identify areas of major concern and to suggest strategies which could be applied in the pre-service science curriculum course. Research was carried out over a period of eight months when student teachers were completing semesters four and five of the three year Diploma of Teaching course. On the second of the two fifteen day teaching rounds each student teacher was required to prepare and teach a science unit. The unit preparation was assessed before the round and students, lecturers and classroom teachers evaluated the teaching at its completion.

A survey was completed by most students after the teaching round (over 90% responded), and lesson and unit evaluations were examined. Further information was obtained from follow-ups to tutorial presentations made by the student teachers and from students' answers to examinations and tests. From the survey information was obtained relating to the student teachers' science background, their confidence in teaching particular science topics, and the topics they preferred to teach. The survey was also used to gauge the student teachers' impressions of the standing of science, particularly in relation to curriculum planning in the schools attended during their teaching rounds.

RESULTS

Background understanding of primary student teachers.

Survey responses from 62 students gave the following information about their secondary school background in science.

TABLE 1
YEAR 11 AND YEAR 12 SUBJECTS COMPLETED

Subject Combinations	Year 11 Students	Year 12 Students
Biology/chemistry/physics	9	1
Biology/physics	3	3
Chemistry/physics	2	1
Physics only	1	1
Chemistry only	1	1
Biology only	25	21
No science subjects	21	34
Total	62	62

These figures show that not only was the scientific background dominated by biology but that half of the students had no science subjects at year 12 level and a third had none at year 11 level. This indicates a low level of participation in science subjects. It therefore appears that important objectives of a primary Science Curriculum course should be concerned with the improvement of student teachers' understandings of scientific concepts, particularly those related to the physical sciences, and with creating interest and enthusiasm towards science.

Topics chosen for teaching units.

Using survey results and by checking the contents of the units of work submitted by students it was possible to classify many of the topics into the broad areas of physical science and biological science. Some were unable to be classified in this way as they showed a high level of integration - an arrangement that is generally viewed very favourably. Biology accounted for about two thirds of those classified. Where the topic was chosen by the classroom teacher biology topics were only slightly more popular than physical science topics. While this may suggest a better balanced science curriculum, a few students felt that supervising teachers selected the particular topics because they were not confident with them themselves.

Student teachers' confidence in chosen topics

The survey responses showed that student teachers initially felt more confident with the science content when they chose their own topic, but after preparation there was little difference in content confidence between these students and those who had the topic chosen for them. This suggests that after the initial feelings of disquiet they accepted the topic and made efforts to reach an adequate knowledge level.

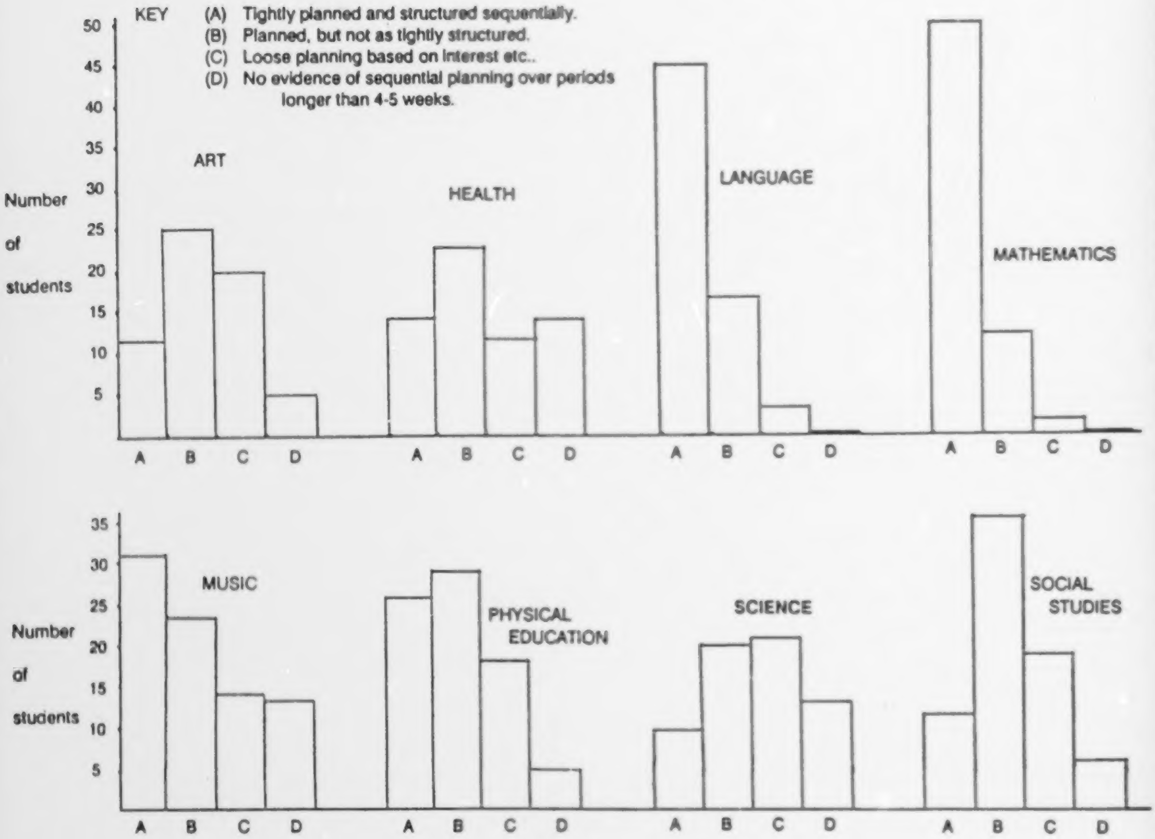

Fig. 1. Student Teachers' Perceptions of the Nature of Curriculum Planning in Primary Schools

Views of curriculum planning

Student teachers were also asked to categorize the nature of curriculum planning in their schools in eight different curriculum areas under one of the following headings:-

A. Tightly planned and structured sequentially.
B. Planned, but not as tightly structured.
C. Loose planning based on pupil interest etc..
D. No evidence of sequential planning over periods longer than 4-5 weeks.

The student teachers' responses were collated and are shown in Figure 1.

Clearly student teachers felt that the curriculum of most other subject areas (particularly mathematics and language) were more highly structured than science. The use of specialist teachers occurred mainly in music, physical education and art, and curricula were generally seen to be more structured in classes with specialists teachers.

DISCUSSION

It seems that either many teachers do not agree that the aims of science education are most likely to be achieved in a sequentially planned program or they do not think that science has the significance to be deserving of such detailed and sequential planning. This problem is not unique to Victoria or to Australia. Researchers in the United States have shown that over half of their elementary teachers rank science fourth or fifth out of five subjects (Manning et al., 1981; Mechling, 1982; Westerback, 1984). More ominous is the suggestion that, consciously, teachers do neither of these things. They are expected to prepare and follow a detailed program in language and mathematics and they do so. No such expectation exists for science in Victorian primary schools and this, coupled with a lack of confidence exacerbated over time, results in the non-sequential type of courses described by our student teachers.

The most recent comprehensive "official" science curriculum publication in Victoria is "The Science Framework P-10" (Malcolm et al., 1987). A teacher with limited confidence in teaching science would not find "The Science Framework" easy to read and I suspect, many are still not familiar with it. The book includes a case study of curriculum development in a fictitious country town called Mt Craig. Interestingly, a number of primary schools seem to be using the program developed in the case study as their own, at least in part, in preference to designing one for their school. This suggests that the provision of more guidance in terms of what to teach would not go astray.

The frameworks book includes an example of primary unit planning using an approach based on an unplanned event: a spider lurking above the classroom doorway. Certainly personal interest is a great starting point for a science unit, but I believe that the need to develop planned and coherent programs is not assisted by an example of planning based on an apparently random event. This example could give the impression that a science course need not be structured overall, but could consist of discrete units based on student interest at the time. A lack of structure may be one factor which is preventing science from holding the position it deserves in the primary school curriculum. The provision of more structured courses may be welcomed by many teachers even though the nature and processes of science learning do not lend themselves to the tight sequencing which occurs in mathematics courses.

Case study evaluations of a number of Ballarat University College graduates teaching in nearby schools indicates that often their confidence in teaching science actually decreases as their teaching experience increases and that curriculum work at College seems to lose its impact within a year or so if graduating teachers are not placed in a school where science is highly valued and where there is sufficient science equipment. Our observations also suggest that in some cases the process approach to science teaching dominates to the point where the science content becomes insignificant. I believe that if a child is learning science then the development of scientific concepts and the building up of a body of knowledge is an essential part of this learning. Therefore process and content need to go hand in hand. All of these factors should be considered in a pre-service science education course.

The Science Curriculum Course at Ballarat University College

The data collected strongly suggest a link between the students' science background and their science teaching, as those who had completed year 11 or 12 science subjects indicated that they felt more confident in teaching their units. This supported the findings of the review panel and is consistent with research in other countries. For example, in "Science 5-16" (Department of Education and Science, 1985) it was stated that "the greatest obstacle to the continued improvement of science in primary schools is that many existing teachers lack a working knowledge of elementary science." Studies in the United States found that only 22% of P-6 teachers felt they were well qualified to teach science while 63% thought they were well qualified to teach reading. (Gerlovich et al., 1981). It was therefore decided to include more activities designed to improve student teachers' understanding of scientific concepts in the course.

The chosen structure provides maximum opportunity for integration in the development of background knowledge and curriculum skills and understandings and more than half of the tutorial time involves student presentations. Lectures address background knowledge and curriculum issues. A textbook, "An Introduction to Science", (Boden et al., 1988) is used by students to supplement the topics covered in lectures and two tests per semester evaluate student progress in these areas.

In the tutorial sessions students give presentations based on listed topics. Typically each two-hour tutorial has three presentations which, when combined, form the outline of a unit of work. The presenters are encouraged to involve the rest of the group in learning activities and are required to issue handouts. Using this approach, teaching and learning activities and content knowledge are introduced in a small group situation while the linking of the three presentations emphasizes the sequential nature of science learning.

Some of the presentations are made in a local primary school. This program enables the children to experience a complete unit of work which runs for five weeks and it provides an illustration of the way we believe science should be taught in primary schools. If the student teachers' work can be seen as valuable for both themselves and the primary children then in the future it may be possible to set it up as an exemplary program for science teaching in primary schools, and perhaps through it initiate changes in the way science is being taught.

REFERENCES

Boden, A., Branagan, D., Davies, J., Giutronich, J., Ross, I. & Strahan, R. (1981). An introduction to science. Marrickville, N.S.W., Science Press.

Department of Education and Science (1978). Primary education in England. London, H.M.S.O.

Department of Education and Science (1985). Science 5-16: A statement of policy. London, H.M.S.O.

Gerlovich, J., Downs, G. & Magrane, G. (1981). How essential is science at the elementary level? Science and Children, 19, 22-24.

Malcolm, C., Cole, J., Hogendoorn, B., O'Keefe, D. & Reid, I. (1987). The Science Framework P-10. Victoria, Ministry of Education.

Manning, P., Esler, W. & Baird, J. (1981). How much elementary science is really being taught? Science and Children, 19, 40-41.

Mechling, K., Stedman, C. & Donnellson, K. (1982). Preparing and certifying science teachers. Science and Children, 20, 9-14.

Speedy, G., Annice, C., & Fensham, P. (1989). Discipline review of teacher education in mathematics and science. Volume 1. Report and recommendations. Canberra, Australian Government Printing Service.

Summer, S. (1989). Some primary teachers' understanding of the concepts force and gravity. Project working paper No. 2 (Oxford, Department of Education Studies, Primary School Teachers and Science Project).

Westerback, M. (1984). Studies on anxiety about teaching science in preservice elementary teachers. Journal of Research in Science Teaching, 21, 937-950.

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TEACHING AND REPORT WRITING IN PRIMARY SCIENCE: CASE STUDIES OF AN INTERVENTION PROGRAM

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ABSTRACT

Relatively little research has been conducted to monitor the role of writing in science lessons. This paper reports the findings of four case studies concerning the teaching and writing of science in isolated one-teacher schools. The teachers participated in an intervention program that aimed to facilitate the teaching of enquiry-based science. This program introduced an innovation consisting of instructional materials and a teaching approach. A multi-site case study design was used which involved regular lesson observations at the schools over a period of 12 months. Documents in the form of the students' written reports were used to supplement data regarding the teachers' use of the innovation. There was a variation in the extent and method of use of the innovation which was evident in the students' reports.

INTRODUCTION

Recent reports have acknowledged the difficulties that primary teachers experience in implementing science (Australian Foundation for Science, 1991; Department of Employment, Education and Training, 1989). This is especially the case in one-teacher schools in which the teacher has the dual responsibility of instructing a K-6 class and administering the school. Studies in the USA (Barker, 1984) and in Australia (Wilson, 1992) have shown that non-teaching duties in these schools often take more than 15 hours per week which leaves little time for lesson preparation. Consequently, the teaching of science is often neglected in these schools (Patrick & Galton, 1990).

In 1988, a project commenced to develop an innovation to address the needs of teachers in isolated one-teacher schools in the far west of NSW. It was developed in collaboration with the teachers over two years and consisted of instructional materials and a teaching approach. The materials consisted of 18 science kits with activity sheets and equipment designed for the students to use. The approach aimed to provide teachers with a simple framework to encourage students to develop investigating and problem solving skills (Hoban, 1990). An intervention program was designed to support the teachers in their use of the innovation. This commenced with a two-day inservice course and included monthly follow-up visits to each school to assist the teachers. To maintain confidentiality, schools have been given pseudonyms in this paper.

As part of the teaching approach, the students were encouraged to write informal reports like a narrative. If the teacher used the approach, then the students' written reports should reflect a process of investigation. Emmitt and Pollock (1991) defined the role of writing:

> The process of finding words to express our thoughts enables our thoughts to grow... we review our knowledge, actively apply our understanding, analyse and synthesise what we mean, and constantly evaluate the text we are composing as we move back and forth to create meaning for ourselves and others (p. 177).

The intervention program aimed to encourage the students to use the instructional materials and to write about their investigations using the three questions "What did you do?", "What happened?" and "Why?". In addition, students from each school were interviewed to ascertain their perceptions about science.

The purpose of the research was to monitor how each teacher used the innovation over a period of 12 months to address the following research questions:

- How did the teachers use the teaching approach?
- How did the teachers use the instructional materials?
- What were the students' perceptions about science?

PROCEDURE

A multi-site case study design was used to evaluate the outcomes of the intervention program. Various quantitative and qualitative methods were used to monitor the teachers' use of the innovation.

- Lessons were observed regularly using an innovation configuration checklist (IC). This listed the five components of the innovation with variations of use for each component. This was tried out in a pilot study and subsequently modified in light of teacher interviews and lesson observations to increase validity (Heck, Stiegelbauer, Hall & Loucks, 1981). This instrument indicated whether the teacher was using the instructional materials and the instructional approach at an unacceptable, acceptable or ideal level as designated by the developer. A co-researcher and the writer used the checklist to observe four lessons in an attempt to establish internal reliability. The number of agreements was 85% on a point by point basis.

- Documents in the form of students' written reports were analysed to ascertain if the students were encouraged to write their own reports and if they provided evidence of a process of investigation as recommended by the teaching approach.

- Several students were interviewed at each school to ascertain their perceptions about science.

RESULTS

Case Study 1: River Public School

This school is located 600 km from Sydney in western NSW. The village has a population of 22 with a pub, a post office, a petrol garage and 15 houses. The one-teacher school has 8 infant students and 10 primary students. An interview with the teacher before the intervention revealed that she regularly taught science and that she had tried out some of the science kits.

The teacher's use of the innovation was monitored in seven lessons over 12 months. Data collected using the IC are shown in Table 1 and indicate that the teacher used both the instructional materials (components 2 and 3) and approach (components 4 and 5) in an ideal way from the beginning of the intervention program.

TABLE 1
IC CHECKLIST DATA FOR LESSONS OBSERVED AT RIVER PUBLIC SCHOOL

Innovation Component	12/6/90	24/8/90	12/9/90	12/10/90	12/11/90	16/4/91	26/7/91
	Pre-inter	During intervention				Post-intervention	
1. Lesson content	1	4	4	4	4	4	4
2. Activity Sheets	1	5	5	5	5	5	5
3. Equipment	3	5	5	5	5	5	5
4. Instruct. Approach	3	5	5	5	5	5	5
5. Student Report	3	5	5	5	5	5	5

Note: Component 1: 1 = unacceptable variation; 2 or 3 = acceptable variation; and 4 = ideal variation.

Components 2-5: 1 or 2 = unacceptable variation; 3 or 4 = acceptable variation; and 5 = ideal variation.

Two of the students, Tony (year 3) and Crystal (year 5), were selected at random and their science reports were monitored over 12 months. The reports of the students before the intervention program were the same suggesting that it was likely that they were copied from the blackboard. During and after the intervention program, the students' reports were different suggesting that they wrote about their own science experiences. This indicated that the students were given responsibility to use the activity sheet and the equipment, as they were able to write about the process and outcomes of their investigations.

Crystal was interviewed at the end of the intervention program and described how she conducted an investigation and wrote her report:

GH: So when you do an experiment, what do you do?

C: Mrs __________ gives us a sheet of paper and we discuss that first and then we go and make our designs to see if they work.

GH: How do you know what to write down?

C: You put the model of what you made or whatever in front of you, that helps you to remember things, and you look at the sheet of paper and look at the picture.

Tony described how he conducted an investigation and wrote about it:

GH: Can you describe for me what you do in a science lesson?

T: Sometimes we make these things and sometimes we test them.

GH: What do you do then?
T: We come back inside and write down all the things about it and what we discovered.
GH: How do you know what to write?
T: You think of all the things that we did.

In the lessons observed, the teacher used the G-TIME approach and encouraged the students to use the instructional materials and to be responsible for their investigations. This interpretation was supported by the students' written reports and interviews. The teacher could be called a "spirited" user as she used the innovation in an ideal way throughout the intervention program.

Case Study 2: Copper Public School

Copper is also in western NSW, 700 km from Sydney. The village has a small licensed club, a general store that acts as a post office and a garage. The population of the village is 22 and there are 12 houses in the village. The teacher was new at the school and had not participated in the development of the innovation. At the beginning of the intervention program, the teacher thought that the innovation should provide a common ground of knowledge for students going to high school which was not consistent with the goal of the innovation and he did not have a positive perception about enquiry-based science.

The teacher's use of the innovation was monitored on seven occasions over 12 months. Data collected using the IC are shown in Table 2 and indicate that the teacher used the instructional materials (components 2 and 3) in an acceptable way, but not the instructional approach (components 4 and 5) during the intervention program.

TABLE 2
IC CHECKLIST DATA FOR LESSONS OBSERVED AT
COPPER PUBLIC SCHOOL

Innovation Component	12/6/90	24/8/90	12/9/90	12/10/90	12/11/90	18/4/91	24/7/91
	Pre-int.	During intervention				Post-intervention	
1. Instruct content	1	4	*	4	4	4	*
2. Activity Sheets	1	5	*	1	1	1	*
3. Equipment	2	5	*	4	4	2	*
4. Instruct. Approach	2	4	*	2	2	2	*
5. Student Reports	2	3	*	1	1	2	*

Note: * indicates that no lesson was observed
Component 1: 1 = unacceptable variation; 2 or 3 = acceptable variation; and 4 = ideal variation.
Components 2-5: 1 or 2 = unacceptable variation; 3 or 4 = acceptable variation; and 5 = ideal variation.

Two students, Brian (year 6) and Rachel (year 5), were selected at random and their science reports were monitored over 12 months. Their reports support the interpretation from the data in Table 2 that the teacher used the instructional materials, but did not use the instructional approach. Before the intervention program, the students did not have a science workbook and the teacher stated that any worksheets used were placed in a general folder. After the intervention program, the students acquired a workbook for science, however, most of the reports were worksheets and did not provide evidence of a process of investigation.

Brian was interviewed at the end of the intervention program and he described how he conducted an investigation and wrote a report. It appeared that he was directed by the teacher in science lessons and he did not have a positive perception about science:

GH: Can you describe what you do in a science lesson?
B: The teacher tells us what to do and we do it.
GH: What do you mean?
B: The teacher tells us what to get and what to do with things. We go and collect the things and do it.
GH: Do you like science?
B: Not really .... we don't do it very often and it's boring.

After the intervention program, Rachel was interviewed with another student, Daniel, by a co-researcher (LA) during a hands-on investigation. It appeared that in they were often directed in science lessons and completed worksheets except in a lesson with a trainee teacher in which the students made their own ideas.

LA: So how do you do a science lesson?
R: We usually get into groups of four or five and we have to make something or work something out.
LA: So when you do have science, do you ever write in your book?
R: We fill in the sheet and stick it in our book, and sometimes when we make things we have to write down how you made it. You write down what you do first and then what comes next.
LA: And would you have to decide what came first and what came second all on your own?
D: No, we would all do the same and fill in the sheet. Once we made our own ideas with Miss ______ [visiting student teacher] we had to make our very own one. The group had to make their own ideas and then do it so they wouldn't be all the same, but in other things we do they are all the same.

In the lessons observed, the teacher used the instructional materials as his teacher resource, but did not use the G-TIME approach. He mainly directed students during the lessons and did not encourage the students to be responsible for their investigations. This interpretation was supported by the students' written reports and interviews. The teacher could be called a "passive user" of the innovation, as he adapted the materials to his usual transmission style of teacher and did not modify his teaching approach.

Case Study 3: Goat Public School

Goat is located in north-western NSW, 700 km from Sydney. The village has a population of 25 and there are nine houses in the village. It has a small hotel, a general store which serves petrol and acts as a post office. At the beginning of the intervention program, the teacher was interviewed and stated that he taught science weekly using demonstration lessons because of the limited equipment in his one-teacher school.

Use of the innovation was monitored on seven occasions over 12 months. At the end of 1990 the teacher left the school and so data for the last two lesson observations refer to a new teacher at the school. Data collected using the IC are shown in Table 3 and indicate that the teacher used the instructional materials (components 2 and 3) and the instructional approach (components 4 and 5) in an acceptable way during the intervention program. It should be noted that the teacher initially did not use the innovation as intended, but did respond to professional advice and modified his use of it.

TABLE 3
IC CHECKLIST DATA FOR LESSONS OBSERVED AT GOAT PUBLIC SCHOOL

Innovation	13/6/90	23/8/90	23/9/90	11/10/90	13/11/90	18/4/91	24/6/91
Component	Pre-int.	During intervention				Post-intervention	
1. Lesson content	1	4	4	4	4	*	1
2. Activity Sheets	1	4	4	5	5	*	1
3. Equipment	5	3	5	5	5	*	3
4. Instruct. Approach	4	2	4	5	5	*	2
5. Student Report	1	2	3	5	5	*	1

Note: * indicates that no lesson was observed.
Component 1: 1 = unacceptable variation; 2 or 3 = acceptable variation; and 4 = ideal variation.
Components 2-5: 1 or 2 = unacceptable variation; 3 or 4 = acceptable variation; and 5 = ideal variation.

Two students, Naomi (year 2) and Emma (year 5), were selected at random and their science reports were monitored over 12 months. Their reports support the interpretation from the data in Table 3 that the teacher used both the instructional materials and the instructional approach. Before the intervention program, the students mainly copied work from the blackboard. During the intervention program, the students wrote about the processes and outcomes of their own investigations.

The two students were interviewed at the end of the intervention program to ascertain their perceptions about science. Emma (year 5) described how she conducted her investigations and then wrote a story about them:

GH: How do you normally do science?

E: Usually we get into pairs and Mr __________ gives out sheets with instructions to make whatever and then we go outside and do what ever with them. Then we come back inside and write how we might be able to make them do any better like how we could make our land boats go any faster, how we could make our paper aeroplanes fly better. Then we write a little story about what we did.

Naomi (year 2) was also interviewed. She stated that handwriting and reading were her favourite subjects.

GH: What is your third favourite?

N: Science.

GH: Is it, why's that?

N: Because you can make things and you can write things down like what you are doing today. You can learn about trees and the world.

GH: And how do you write it up?

N: We put questions on the board and we have to answer them. Sometimes we have to write a lot about it —what we did and how to make an aeroplane go better.

In the lessons observed, the teacher initially used the instructional materials as a teacher resource, but did not use the G-TIME approach. During the intervention program he encouraged the students to be responsible for their investigations. This interpretation was supported by the students' written reports and interviews. He could be called a "developing user" as he modified his use of the innovation during the intervention program. A new teacher was appointed to the school at the beginning of 1991 and was not familiar with the innovation. She passed the responsibility for teaching science to the relief teacher who used parts of the innovation as her own resource.

Case Study 4: Mulga Public School

Mulga is also in north-west NSW, 800 km from Sydney. The village has a population of 17 people and there is a pub, a post office and nine houses. The one-teacher school has six primary students and four infant students. The permanent teacher lacked confidence to teach science and gave this responsibility to the relief teacher who came to the school every Thursday. An interview with the relief teacher at the beginning of the intervention program revealed that he had a transmission approach to teaching science.

The relief teacher's use of the innovation was monitored in seven lessons over 6 months. Data collected using the IC are shown in Table 4 and indicate that the teacher initially did not use the innovation as intended. He did, however, use both the instructional materials (components 2 and 3) and approach (components 4 and 5) in an acceptable way towards the end of the intervention program. In 1991 the permanent teacher taught science using the innovation and data in the last two columns refer to this teacher.

TABLE 4
IC CHECKLIST DATA FOR LESSONS OBSERVED AT MULGA PUBLIC SCHOOL

Innovation Component	13/6/90	23/8/90	13/9/90	13/10/90	12/11/90	18/4/91	24/6/91
	Pre-int.	During intervention				Post-intervention	
1. Lesson content	1	1	1	4	4	4	4
2. Activity Sheets	1	1	1	4	4	1	1
3. Equipment	4	2	4	4	5	5	5
4. Instruct. Approach	2	3	4	3	4	4	4
5. Student Reports	2	2	1	2	3	3	3

Component 1: 1 = unacceptable variation; 2 or 3 = acceptable variation; and 4 = ideal variation.

Components 2-5: 1 or 2 = unacceptable variation; 3 or 4 = acceptable variation; and 5 = ideal variation.

Two of the students, Juanita (year 5) and Chanel (year 5) were selected at random and their science reports were monitored over 12 months. The reports of the students before the intervention program were the same suggesting that it was likely that they were copied from the blackboard. The reports during the intervention program were different and indicate that the teacher used the instructional materials but his use of the instructional approach was limited.

At the end of the intervention program, Juanita and Chanel were interviewed to concerning their perceptions about science. Juanita did not have a positive perception about science.

GH: What about science, do you like that?
C: Not really.
GH: Why?
C: I don't know, I just don't like science very much.
GH: Any good reason?
C: No.

Juanita was also interviewed and stated that she liked science and that she explains what she did in a science report:

GH: Why do you like science?
J: Because we sometimes get to make things and we have some games.
GH: What do you mean?
J: Like when we put the broken bones together and then we had a competition to see who made the strongest.
GH: Do you write down what you do?
J: Sometimes.

GH: Do you copy it from the board or write it yourself?
J: We sometimes copy things but mostly we write it ourselves.
GH: How do you know what to write?
J: The teacher tells us to explain what we did.

In the lessons observed, the teacher initially used the instructional materials as a teacher resource and did not use the G-TIME approach. During the intervention program he encouraged the students to be responsible for their investigations. This interpretation was supported by the students' written reports and interviews. He could be called a "developing user", as he modified his use of the innovation during the intervention program.

CONCLUSION

Before the intervention program, science was not extensively taught in the one-teacher schools and students mainly copied science summaries from the blackboard. The intervention program attempted to facilitate the teaching of enquiry-based science by providing instructional materials, an instructional approach and in-service support. This study indicates that the innovation addressed the needs of the teachers, but there were variations in the way it was used. All four teachers used the instructional materials but not in the same way. Three of the four teachers used the instructional approach but not to the same extent. Findings suggest that the teachers readily used the new instructional materials, but a change in teaching approach was a more difficult task. The study emphasised that the implementation of an innovation needs to be accompanied by an ongoing professional development program to address the different ways teachers use them.

Students who were responsible for their own investigations and used the science kits were able to write comprehensive reports. Students who were not encouraged to use the science kits often filled in worksheets. Overall, the written reports of the students provided valuable evidence to monitor how the teacher was using the innovation. This is especially useful to crosscheck data collected in studies using intermittent lesson observations. Teachers should encourage students to be responsible for their science investigations and empower them to write informal reports as a tool for reflective thinking. If necessary, information in these informal reports can be used in later lessons to write a formal science report.

REFERENCES

Australian Foundation for Science. (1991). First steps in science and technology. Summary of the Science Education Focus Group. Australian Academy of Science 28-29 May, Canberra.

Barker, B. (1984, October). One-teacher schools in America today. Paper presented at the Annual Conference of Rural Education Association, Olympia, WA. (ERIC ED 249 038).

Department of Employment, Education and Training. (1989). Discipline review of teacher education in mathematics and science. Canberra: Australian Government Printing Service.

Emmitt, M. & Pollock, J. (1991). Language and learning. London: Oxford University Press.

Galton, M. & Patrick, H. (eds.) (1990). Curriculum provision in the small primary school. London: Routledge.

Heck, S. , Stiegelbauer, S. M. , Hall, G. & Loucks, S. (1981). Measuring innovation configurations: Procedures and applications. Austin: The University of Texas.

Hoban, G. (1990). Problem solving and writing: Hand in hand. Investigating, 7(3), 22-24.

Wilson, P. (1992). Teaching principals: Administrative workload survey. Education, 73(1), 20.

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PROFESSIONAL STANDARDS FOR THE TEACHING OF SCIENCE: AN EXPLORATORY STUDY

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ABSTRACT

The Science Education Professional Development (SEPD) Project was commissioned by the Commonwealth Department of Employment, Education and Training (DEET) as part of its Projects of National Significance Program. Its brief was to develop a national strategy for enhancing the professional development of science teachers. This paper summarises one component of the Project's work, an exploration of the feasibility of establishing professional standards or expectations for teachers of science. The aim was to give clearer purpose and direction to professional development planning and to provide a more valid basis for evaluating science teachers for career development.

PROFESSIONALISING SCIENCE TEACHING

It became clear during the SEPD Project that the absence of 'professional' leadership was one of the major concerns that a national professional development strategy would have to address. Professional development policy for science teachers lacked focus and direction. No one in the science education community had a formal responsibility for exercising leadership in developing standards for science teaching. There was no forum where such discussions could take place.

As a result, the Project team made a number of recommendations that aimed to strengthen the professional roles and responsibilities of the Australian Science Teachers Association, in collaboration with unions and employers. These included:

- establishing standards and expectations for what science teachers should know and be able to do at various career stages;
- setting priorities and goals for the in-service education system to assist teachers to reach and maintain those standards;
- developing valid procedures for the appraisal and evaluation of science teaching ; and
- developing and operating a new system for accrediting programs, and the awards they bear, designed to help science teachers attain professional development standards.

The SEPD strategy represented a 'professionalisation' agenda. It argued that teachers' organisations, such as the Australian Science Teachers Association, should exercise a more vigorous and creative responsibility concerning their own professional development in concert with teacher unions. The parlous 'condition' of science teaching called for such an agenda. It was also a long term agenda, a direction in which it was believed we should move gradually, through seeding programs that steadily established the structures and conditions that supported a more self-regulating profession.

The critical role of such programs would be to strengthen the capacity of the profession itself to generate and document knowledge about the practice of science teaching. We believed the science teachers' associations and science education researchers in Australia had demonstrated the capacity to generate valuable knowledge about science teaching and learning. However, there was a need to mobilise this capacity more effectively in the service of a 'theory-driven' in-service education system than it had been in the past.

This paper summarises work that is reported more fully in the SEPD report Professional Standards for the Teaching of Science: An exploration of what Advanced Skills Science Teachers should know and be able to do (Ingvarson, 1992a). This part of the SEPD Project's work was a first attempt to articulate professional standards for the teaching of science. It aimed to provide a realistic assessment of what would be involved in a later, full scale exercise of developing a professional evaluation system for teaching. Such a system would aim to provide a career path for science teachers based on demonstrable advances in their professional knowledge and skill.

WHY DID THE IDEA OF 'STANDARDS' BECOME IMPORTANT TO THE SEPD PROJECT?

The SEPD Standards report represented a preliminary attempt to clarify some of the things an experienced science teacher should know and be able to do. We embarked on this exploratory exercise into standards because we thought it had the potential to improve the quality of professional development planning for science teachers.

The SEPD Project isolated two fundamental weaknesses in the current provision of professional development for science teachers (Ingvarson, 1992b). The first was the lack of clarity about professional 'development' itself. In other words, a lack of clarity about what science teachers should get better at. This seemed to undermine the effectiveness of the in-service enterprise. Many brief in-service activities were available, but they seemed to be a response to immediate and random priorities and pressures, and to be unrelated to each other. There was little sense of a sequence of experiences or activities related to stages in a teacher's career.

The priorities and pressures setting the agenda for professional development were coming largely from employing authority initiatives, not science teachers' professional associations, or findings from science education research. It appeared that no one in the science education community had, or expected to have, a responsibility for exercising leadership in developing standards for science teaching.

There appeared to be little confidence in a knowledge base for science teaching, although members of the science education community were well aware of many major developments in knowledge about science teaching and learning. As a result, there was little purpose or direction in professional development planning for science teachers over the long term. The lack of confidence in standards, or expectations for professional development, made it difficult to mount convincing arguments to policy makers for increased funding. They were sceptical enough about what was provided currently.

The question of standards for professional development in teaching had become a major national issue as a result of Award Restructuring and the introduction of a career path leading to 'Advanced Skills Teacher' (AST) positions. Within a short space of time, the industrial relations arena had gained the responsibility for setting standards affecting all of Australia's 250,000 teachers. But that arena was proving to be ill-suited to the kind of discussion, research and development essential to setting standards and the development of valid evaluation methods (Chadbourne & Ingvarson, 1991; Ingvarson, 1992).

The science education community, like all professional associations apart from unions, had not been invited to participate in this process. Little reference to research on teaching particular subjects or teacher evaluation appeared to be informing these rapid and significant changes in policy affecting teachers' career structures.

We hoped that the exercise of setting standards would help to draw attention to the extensive knowledge base that existed in science education. We have not had the chance to test this proposition yet, but we suspect the SEPD exercise will reveal that there is a much higher degree of consensus about what 'advanced skills science teachers', for example, should know and be able to do than many in the science education community might have predicted.

The second weakness in the current system was the lack of value placed on professional knowledge and skill, in terms of the career paths available to teachers. The system had not developed adequate mechanisms for recognising the outcomes of professional development and rewarding them through the promotion system.

In other words, the incentive system was weak. There were weak links between professional development and career development: that is, between promotion and evidence of 'advanced skills', or, between pay and professional skill. In a counter-productive way, teachers who focused primarily on extending their professional and classroom skills were treated as if they were not pursuing a career in teaching.

One reason for this divorce between career development and professional development was the lack of consensus about a knowledge base for teaching, based on 'best practice' and research in the specific area and levels of the curriculum that they taught.
Strengthening this relationship was critically dependent on the profession claiming as its own the responsibility for establishing standards for teaching that were a valid reflection of the sophistication of best practice and research in each of the curriculum content areas, and for developing evaluation methods that were equal to the task of giving experienced teachers the chance to demonstrate the quality of their professional knowledge and practice.
If Award Restructuring was to be implemented effectively, it was necessary to clarify what we expected teachers to get better at, to set standards or expectations for development. The beauty of the Advanced Skills Teacher concept was the clearer purpose and direction it could give to professional development planning over the long term. And, potentially at least, it linked evidence of development to promotion and career development.

The SEPD Professional Standards report arose from the need to address these two basic weaknesses in the in-service education system. The papers in that report aimed to provide a starting point for debate in the science education community, about the possibility and desirability of establishing standards, and their potential for improving the quality of professional development planning.

SETTING STANDARDS FOR TEACHING

Teaching, like all occupations, has been caught up recently in Commonwealth pressure to develop 'competency standards'. The National Training Board (NTB), created in 1990, has had the task of developing a uniform Australian standards framework and format. Its role is to assist industrial parties to develop, and then to endorse, national competency standards.

The National Office of Overseas Skills Recognition, created in 1989, works closely with NTB and has been the driving force behind the development of national competency standards for the professions in Australia. More than twenty professions are working on, or have finished, this process. With some financial assistance from NOOSR, the National Project on the Quality of Teaching and Learning and DEET recently funded a preliminary project to develop "National Competency Standards for the Teaching Profession". So far, teacher associations other than unions have not been given a formal role in this process, despite their large memberships. (ASTA has over 6000 members.) The SEPD Project was a means of drawing national attention to this deficiency, as we saw it.

We assumed that the task of establishing standards in education should begin with, and stay embedded in, discussion about what counted as quality learning. Conventional methods of job description or job analysis were not adopted in the SEPD approach. Some that are being used currently (eg. NBEET, 1992) break the responsibilities of teaching into progressively smaller 'units' and 'elements' of work or tasks. The risk with this approach is that the process of checking off competent performance in dozens of specific task areas can obscure or deflect debate about what counts as quality in the overall performance of teaching. The parts may not add up to a valid judgment of the whole, if quality practice of teaching is seen as an appropriate integration and deployment of many competencies in varying contexts.

This turns out to be a traditional problem in educational assessment, such as essay marking; whether to opt for an analytical approach, or more holistic bases for making judgments. As mentioned above, we believed no one was in a position to be dogmatic about the appropriate level for teaching, because the necessary research on the feasibility, reliability and validity of various teacher evaluation methods was still to be done.

One of the valuable aspects of the NOOSR competency-based standards approach is its emphasis on performance as the focus for standards and the evaluation of teachers, rather than less valid proxies for competent performance such as academic qualifications, 'experience', or 'the ability to reflect critically'. The latter may be valuable means to attain standards, but they are not standards in themselves.
There is a problem, however, in finding the appropriate level at which to assess teachers' work or 'performance'. The 'chunks' need to be meaningful components of teachers' knowledge and skill. The risk in holistic methods is that teachers' may be evaluated in terms of 'style', or superstition, (e.g. 'teaching is an inspirational task, like an artist, lacking clear goals and well-developed knowledge of means-end relationships').

On the other hand, the risk with highly analytical approaches is that teachers' judgment and skill will be devalued and their work defined as routine labour, to be evaluated in terms of attitudes, such as loyalty to policy, and behaviours, such as compliance with predetermined procedures.

The SEPD perspective on setting standards

We chose to enter the task at an intermediate level. This was because we believed that teaching is complex and unpredictable work , requiring constant judgment and adaptation to context, and because we believed that there was a rich body of knowledge and skill related to quality learning that teachers should be expected to know and to be able to use judiciously and ethically.

The SEPD Standards exercise was a preliminary sortie into the comparatively unexplored territory of setting standards in science teaching and developing appropriate methods for teacher evaluation. There were no well worn paths or guidelines to follow. We believed there was inadequate experience as yet for anyone to be dogmatic about how this task should, or should not, be done. The exercise was more like reconnaissance than mapping. It was an exploration into some of the best that was known to be possible in science teaching, not a description of what was typical.

Valuable reference points for this report were found in the work of people such as Michael Scriven (1989) and Lee Shulman (1987). Their stances drew attention to the richness and subtlety of the work of good teachers. Scriven argues for a normative list of 'duties' or obligations. He provides a catalogue of what teachers should be held responsible for doing and knowing. His list of core duties, based on a professional consensus, does not mirror necessarily what teachers actually know and do. It is a list of what they should know and do. He sees his core duties list as "an essential requirement in obtaining for good teachers some of the respect they deserve." It is a list that rarely fails to impress in terms of its comprehensiveness. It can be a means "to support the claim that the job is both demanding and diverse . . ." (p. 1).

Shulman constantly seeks to unfold the sophistication of what expert teachers know and do. With his colleagues, he has tried to reveal 'the wisdom of practice' by a variety of research methods, such as comparing novice and expert teachers. The sophistication of expert teacher knowledge emerges in the work of people such as Grossman (1991) and Wilson and Wineberg (1989). One of the most exciting manifestations of this approach is the report of the US National Council for the Teaching of Mathematics (NCTM), Professional Standards for the Teaching of Mathematics (1991). A major contribution of Shulman's work, and others associated with his 'Teacher Assessment Project' at Stanford, is the way in which this research has opened up a refreshing set of innovative methods for giving teachers a chance to show the sophistication of what they know and do.

Our approach built on this work of Scriven and Shulman, and departed from it somewhat as well. Some of the best research in science education has been done in Australia, and we felt that it also provided useful starting points for the development of standards. Much of this work starts with learning science; with questions about what it means to understand science and what counts as quality learning in science. Lampert (1988) also starts from this point in a paper on mathematics that was particularly useful for our purposes.

GUIDELINES TO AUTHORS

Authors were asked to focus on one facet of 'quality' learning in science and to explore what it implied for what teachers should know and be able to do. They were chosen because they were well known and respected members of the science education community in Australia.
The guidelines asked authors to approach the task of setting standards by addressing the question:

> Do we have any confidence about the skills and knowledge we would expect an Advanced Skills Science Teacher to have gained as a result of in-service education, professional reading, appraisal, and other forms of professional development activity?

We asked authors to work through the following steps as closely as possible:

- start from a view of what counted for them as quality learning in science;
- move to an analysis of the kind of teaching that supported that learning;
- examine what teachers needed to know and be able to do to produce that kind of teaching;
- discuss the types of evidence that would provide a basis for evaluating whether teachers had developed that knowledge and skill or not.

We were interested in the following questions. Can science education research provide a valid basis for developing professional standards? How should they be developed? How should teacher evaluation be conducted if its aim was to give recognition to professional development and the complexity and sophistication of quality science teaching and learning?

We saw the task of preparing a more definitive set of 'competencies', or standards, in the future as the responsibility primarily of science teachers and the Australian Science Teachers Association. We had no intention in the SEPD work of usurping what we believed to be their right and proper professional responsibility. It was our hope that they would find our Standards report a useful starting report in their later deliberations. We also provided authors with extracts from the NCTM Standards, which came out at the same time. It was a document of considerable interest to us, not just because it supported what we already believed, that the knowledge base of teaching was much more extensive than most people realised.

We were also interested in the problem of how standards in teaching should be represented. What should professional standards for teaching look like? How should we represent knowledge about science teaching (through propositional knowledge, case knowledge, strategic knowledge?). The long tradition of research on teaching indicated that findings expressed in the form of propositional statements, or if-then relationships, about teacher behaviour and student learning, were of limited value. Such statements gave little indication of how to put them into practice. They were divorced from context and the particular content being taught.

We believed the same problem was being created in the way criterion statements for AST positions were being expressed. Statements such as, "Teachers should use a range of teaching strategies", provided limited guidance in making professional judgments about the quality of teaching of particular teachers in particular subject areas. Such statements gave AST assessment panels little idea of what they might expect applicants to know and be able to do in their particular area of teaching expertise.

LESSONS FROM THE SEPD EXERCISE ON STANDARDS

Images of quality. The SEPD exercise on standards indicates that there is increasing justification for the science education community to claim that it has an extensive knowledge base for its practice. It is appropriate for its professional body to claim that this knowledge base should become the main reference point when establishing long term goals for the in-service education system, rather than employer or government policy.

The contributions to the SEPD Standards Report show that the profession is capable of providing multiple images of what counts as 'quality' learning in science. They demonstrate that the profession can provide concrete examples of what it is trying to achieve, and what it values in terms of student learnings and outcomes. The images of quality learning in science in the report were rich and sophisticated. It was possible to develop a wide range of case studies of 'best practice' that were convincing demonstrations of specialist understandings of what it meant to learn and understand science.

We believed that this knowledge should play a more central role in the processes used for establishing national competency standards for the teaching profession.

Standards need to be content-specific. While there may be considerable commonality across subjects in the duties that teachers should carry out, the SEPD exercise, and recent research, such as that mentioned above, indicates that standards are of limited applicability unless they are embedded in what is being taught and to whom it is being taught. No valid procedures for evaluating teachers could ignore the content or subject-specific nature of teaching skills (Leinhardt et al., 1991).

Any proposed teacher evaluation system for career advancement must be capable of reflecting the complexity of quality teaching in science. The SEPD report served the purpose of showing that the knowledge base for science teaching is much more extensive than many science teachers realise. We have rarely tried to articulate and codify its extent. Because it has not been codified, teachers themselves have tended to underestimate, and lack confidence in, the extent of their own specialist knowledge.

This knowledge base is being ignored in current procedures for establishing standards that affect the career paths of science teachers, with detrimental effects on the credibility of the methods that are being used for teacher evaluation. This also undermines the positive role that standards can play in appraisal and professional development.

How should standards be presented? The best methods for presenting a 'standard' in science teaching are not yet clear. We are still not sure what a standard for teaching should look like, nor how knowledge about teaching may best be represented. It is clear that simple verbal statements, maxims, or propositions are inadequate for the task. The papers in the Standards report suggest that standards may best be represented through examples, or 'cases' of teaching; rich 'stories' with the capacity to illustrate the full context of quality practice, and the reasoning behind that practice. But we are still a long way from anything that could be considered a comprehensive coverage of standards for science teaching, and no one should believe it will be easy to do.

We asked authors to suggest valid procedures for giving recognition to quality science teaching and learning. Many excellent suggestions were made that would be worth testing in later projects run by science teachers. It was clear that multiple forms of evidence would be necessary for reliable assessments, a view consistent with other commentators (eg. Scriven, 1989). Alternative ideas for assessment which are emerging, such as performance exercises and portfolios (Haertel, 1991; Bird, 1990), were strongly endorsed by authors and would be worth exploring further. There was clearly a need for a major project on developing standards and better methods of teacher evaluation than those currently in use. The SEPD final report recommended that the Australian Science Teachers Association coordinate such a project, with seeding funds provided by the Commonwealth Government.

Teacher Evaluation. Authors also made it clear that assessors would need extensive experience and expertise in the teaching of science if their evaluations were to be valid, because their assessments of quality would have to rely heavily on professional knowledge and judgment.

The SEPD work therefore suggests that it would be advisable to review the validity of school-based panel assessments for advanced skills teacher status, as currently used in most systems. Applicants commonly report that panels ask no questions related to how they teach their subject. Under current practice in Victoria, these panels may have no members with experience or expertise in the same subject area as the applicant. As a result, their ability to conduct interviews with any depth, can be very limited. There is no possibility in these brief interviews to evaluate portfolios containing documentation of a teacher's work, for example.

For these reasons, current methods of panel assessments are proving to be unfair as well as invalid, leaving teachers with the feeling that the process was neither professionally, nor publicly, credible.

Another weakness of the Victorian school-based panel approach is its inability to guarantee comparability in standards applied from school to school, or from system to system. The practice of using one outside person on two or three panels does little to meet this important criterion, especially when that person need not have any expertise in the teaching area in question. Teachers sending the same application for AST 2 and 3 positions to several schools are currently receiving widely discrepant judgements from school-based panels about the extent to which their applications meet the criteria set for these positions.

As a result of these weaknesses, the current methods for assessing teachers for AST status are unable to serve the central purposes for which they were introduced; to provide a professional qualification or certification that a teacher has reached a professional standard in their field of teaching, or to provide a guide and an incentive to professional development.

The SEPD Project work on standards indicates that it would be fruitful to continue experimenting with methods of setting standards and conducting assessments within subject-specific teaching areas. Current AST procedures should not be regarded as set in stone. It was highly unlikely that anyone would be able to get these methods right the first time. They are very complex assessment exercises to develop and validate (Haertel, 1991).

Future directions: A National Science Teaching Council. The SEPD Project suggests an alternative approach; that science teachers could be assessed instead by means of standards and procedures developed by their professional association, in conjunction with the current proposal for a National Teaching Council. It is conceivable that the Australian Science Teachers Association could develop its own trained panels, operating at state or regional levels, and following guidelines determined in conjunction with a national professional body. Such a system for teacher assessments could save local school-based panels considerable time and anguish, if professional competence only had to be established once for someone applying, for example, for AST 1, 2, or 3 status. The validity and comparability of these assessments is likely to be much higher that those of school-based panels using the limited range of evidence that is currently available to them.

There are several exciting new approaches to the evaluation of teaching that science teachers have been developing themselves in the USA, which make ingenious use of a wide range of information sources (e.g Baratz-Snowden, 1991; Collins, 1991; Wolf, 1991). There is no reason to believe that Australian science teachers could not manage to develop and conduct their own performance evaluation system.

To perform the above functions, the profession itself must to learn how to establish professional development standards and valid methods for teacher evaluation. The SEPD Project indicated that such a task would take three to four years at least and require several expert staff initially. After this, the process would, of course, need to be on-going in a small way, as changes took place in the knowledge base of science teaching. Any suggestions that valid standards or 'competencies' and assessment methods can be produced in a few months are not supported by our work, nor the work of groups such as the National Board for Professional Teaching Standards (Baratz-Snowden, 1991), the Teacher Assessment Project (Haertel, 1991), and the Centre for Research on Educational Accountability and Teacher Evaluation (Stufflebeam, 1991).

REFERENCES

Baratz-Snowden, J. (1991). Performance assessments for identifying excellent teachers: The National Board for Professional Teaching Standards charts its research and development course. Journal of Personnel Evaluation in Education, 5 (2), 133-146.

Bird, T. (1990). The schoolteacher's portfolio: An essay on possibilities. In J. Millman & L. Darling-Hammond (Eds) The new handbook of teacher evaluation: assessing elementary and secondary school teachers. (2nd edn.) London: Sage Publications.

Chadbourne, R. & Ingvarson, L. C. (1991). Advanced Skills Teach 1: Lost opportunity or professional breakthrough. IARTV Seminar Series, No 9. Jolimont, Victoria: Incorporated Association of Registered Teachers of Victoria.

Collins, A. (1991). Portfolios for biology teacher assessment. Journal of Personnel Evaluation in Education. 5 (2), 147-168.

Grossman, P. (1991). The making of a teacher. New York: Teachers College Press.

Haertel, E. H. (1991). New forms of teacher assessment. In G. Grant (ed.) Review of Research in Education, Vol. 17. Washington, D.C.: American Educational Research Association.

Ingvarson, L. C. (ed.) (1992a). Professional standards for the teaching of science: an exploration of what Advanced Skills Science Teachers should know and be able to do. A report of the Science Education Professional Development Project, funded by the Department of Employment, Education and Training.

Ingvarson, L. C. (1992b). A strategy for the professional development of science teachers. A report of the Science Education Professional Development Project, funded by the Department of Employment, Education and Training.

Lampert, M. (1988). What can research on teacher education tell us about improving quality in mathematics education? Teaching and Teacher Education, 4 (2), 157-170.

Leinhardt, G., Putnam, R., Stein. M. K. & Baxter, J. (1991). Where subject knowledge matters. In J. Brophy (ed.). Advances in research on teaching. Volume 2. Teachers' knowledge of subject matter as it relates to their teaching practice. Greenwich, CT: JAI Press.

National Board for Employment, Education and Training. (1992). A national training framework for careers coordinators: A proposal. Canberra: Australian Government Publishing Service.

National Council of Teachers of Mathematics. (1991). Professional standards for teaching mathematics. Reston, VA: NCTM.

Scriven, M. (1989). The state of the art in teacher evaluation. In J. Lokan & P. McKenzie, Teacher appraisal. Hawthorn, Victoria: Australian Council for Educational Research

Shulman, L. (1987). Those who understand: Knowledge growth in teaching Educational Researcher. 15 (2), 4-14.

Stufflebeam, D. (1991). CREATE Newsletter, Kalamazoo, MI: Center forEducational Accountability and Teacher Evaluation, The Evaluation Centre, Western Michigan University.

Wilson, S. & Wineberg, S. (1989). Subject matter knowledge in the teaching of history. In J. Brophy (ed.). Advances in research on teaching. Greenwich, CT: JAI Press.

Wolf, K. (1991). Teaching portfolios. San Francisco: Far West Laboratory for Educational Research and Development.

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PRIMARY SCIENCE EDUCATION: VIEWS FROM THREE AUSTRALIAN STATES

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ABSTRACT

This paper reports an empirical study of science education in Australian primary schools. The data show that, while funding is seen as a major determinant of what is taught and how it is taught, teacher-confidence and teacher-knowledge are also important variables. Teachers are most confident with topics drawn from the biological sciences, particularly things to do with plants. With this exception there is no shared body of science education knowledge that could be used to develop a curriculum for science education. There was evidence that most teachers see a need for a hands-on approach to primary science education involving the use of concrete materials. A substantial proportion of teachers agree that some of the problems would be alleviated by having a set course together with simple, prepared kits containing sample learning experiences. Any such materials must make provision for individual teachers to capitalise on critical teaching incidents as they arise and must not undermine the professional pride that teachers have in their work.

INTRODUCTION

Curriculum can be considered as consisting of two fundamental components; the substantive content, or text, and the contextual content, or context (Charron, 1991; Dawson, 1991). The selection of content from science text is problematic and there are widely divergent views about what should be in the curriculum. Those who argue for a process approach emphasise tools such as observation, formulating hypotheses, classification, communication etc. Others argue that science knowledge ought to be given equal or greater weight and for this reason the teacher must have a body of personal science knowledge. The context of science is also problematic because there is now less emphasis, among science educators, on science as the mechanistic discovery of objective reality (Hurd, 1990). We have also become more concerned about issues such as the accountability of scientists, children's learning strategies, the development of technological competence, the effects of manufacturing industry on the environment and the role of science and technology in economic recovery (Jeans, 1992).

Many of these issues have been well discussed in relation to post-primary science education although there seems to be few empirical studies that have sought to ascertain the strength and diversity of teacher opinion about these issues. Even fewer studies have examined if and how contemporary thinking about science education has affected primary science education. Presumably, if there is to be science education in the primary school (Blake, 1977; Jeans, 1992) then it is better to have a systematic rather than an unsystematic program. Similarly, what is taught and how it is taught should support rather than conflict with the science education programs of the post-primary school. For these reasons the study reported in this paper examines the opinions and beliefs of generalist primary school teachers working in schools in three Australian states.

SAMPLE

Denominational and government schools in three states were sampled. Approximately 1,000 questionnaires were mailed to the principals of 281 schools and responses were received from 388 teachers (256 females, 127 males, 5 not known). Since the number of teachers in the schools was not known in most cases it is difficult to give a meaningful response rate but it was not less than 38%. It is considered that the response rate was reasonable for this kind of survey. The average age of the sample was 35.9 years and the mean length of teaching experience was 12.2 years. Approximately half the sample had a three year teaching qualification and about half had a four year teaching qualification.

METHOD

The method adopted for this study was based on a similar study reported in Jeans and Farnsworth (1991). Each teacher in the sample was asked to complete a questionnaire consisting of six descriptive variables, eighteen 'strength of opinion' variables arranged as 11 point Likert-type scales, nine structured report variables and four open-ended items. It was clear from the returns that the teachers had taken some care to give considered views. Many made additional comments that proved very helpful in forming a general picture of the determinants of what is taught and how and why it is taught in primary science education. In the data that follow means and standard deviations are noted to provide an indication of the strength and spread of opinion around the mean value.

RESULTS

Curriculum decisions

Every teacher makes curriculum decisions and the authors of the study were interested to know who and what influences those decisions. For example, are teacher colleagues more influential than source books? The data are shown in Table 1. Resource books clearly form the most significant source of information. This is not surprising because most states have produced resource books that have outlined teaching-learning activities. The isolation of rural schools in Australia might be an additional influence on the data obtained. Whatever the reasons it is clear that science education resource books need to be carefully designed so that the information in them is readily accessible, current and easily translated into classroom action. However, it is probable that the range of resource books consulted is quite narrow. The role of textbooks and other resource materials in primary science education has recently been studied by Shymansky, Yore and Good (1991). These authors emphasise the constraining effects that over-reliance on textbooks can have on science education.

TABLE 1
INFLUENCE ON CURRICULUM DECISIONS

Resource books	357 *	(64%)
Colleagues	112	(20%)
Other	53	(9%)
Consultants	37	(6%)
Principal	3	(1%)

* Many teachers made multiple responses

The Principal's role in science education curriculum decisions is interesting because it is essentially non-existent. No-one ought to expect a Principal to be expert in all of the curriculum areas but one might well expect that she would play an important part by feeding policy advice into the curriculum development process. This needs to be the subject of further research. Approximately 9% of the responses had to do with other sources of assistance. These ranged across videos, films, curriculum packages and personal knowledge and experience. Two responses specifically mentioned class-interests but this is derivative in the sense that it is a reason that one might choose certain teaching content but it does not indicate the source of such content.

Perceptions of science education

In order to obtain a global profile of how the sample perceived primary science education teachers were asked to respond to a list of 22 randomly ordered stimulus words (12 positive, 10 negative. On average, 6.5 times more positive than negative stimulus words were chosen. Typically primary science was described as 'fun', 'investigative', 'relevant' and 'finding out'. When asked to contribute other descriptors about one in four of the sample responded and added positive words like 'positive', 'exploring' and 'simple'. A few process words were given: 'hypothesising', 'analysing' and 'questioning'. Negative words included 'expensive', 'difficult', 'confusing' and 'time-consuming'. One concludes therefore that the sample had a positive view of primary science and saw it as fun, exciting challenging, absorbing, involving 'what if', 'hypothesising' and 'finding out'. None of the teachers mentioned descriptors related to technology or gender issues.

School-based curriculum development

Whether teacher expectations of content-adequacy are realistic or not, the practising teacher will make curriculum choices. At one level this might involve choosing one resource or text book rather than another. At another level the teacher might well be involved in school-based curriculum development (SBCD). SBCD contributes to the professionalism of teaching to the extent that it gives teachers some control over the selection of curriculum content and processes (Marsh, Day, Hannay & McCutcheon, 1990; Smith, 1985). It is demanding of teacher-time and SBCD that does little more than rediscover the wheel must be weighed against other demands made on teachers. The mean scale value of teacher opinions about SBCD was 7.1 (s.d. 2.4). The midpoint on the scale used was 'OK if texts not available'. There is therefore reasonable teacher support for SBCD. Using a general linear model for the ANOVA, female teachers showed a significantly stronger commitment to SBCD ($p = 0.047$).

A set course

The concept of a set curriculum as an alternative to SBCD was studied. The mean value for the item was 5.9 (2.6) where 5 indicated 'I wouldn't mind'. There is therefore more support for SBCD than for a set curriculum. Older teachers were significantly more likely to favour a set course than younger teachers ($p = 0.027$).

Equipment

SBCD takes some account of the resources that the school has available at any given time and it takes some account of significant characteristics of the local environment. The equipment available is a matter of the funding priority. The data from the sample in this study suggested that availability of equipment was a significant impediment to the teaching of science. A mean of 7.3 (2.8) could indicate that teachers would teach more science if there was more equipment available. There might well be disagreement about the content of science education but there are very few who would argue against the value of learning the processes of systematic observation, comparison and classification; all of which require materials.

A general question was asked about generic equipment such as libraries, television and video-tapes. These were strongly supported with the qualification that they should not be used to replace 'hands on - let's find out' experiences. The benefit of television and video-tape in illustrating phenomena such as flotation was noted.

Support staff

Even though the equipment actually needed for most primary science education is very simple some organisational skill is needed to ensure that the equipment is available and ready when it is needed. The authors wondered if the provision of an assistant to take care of these organisational matters would have any effect on what is taught and how much is taught. The mean scale value of 7.1 (3.4) indicated that the availability of an assistant would be likely to promote primary science education. Acutely aware of the (assumed) funding implications a number of teachers noted that an assistant would be a good, but impractical, idea.

Importance of science education

Science education is one of seven or eight curriculum areas that compete for teacher time and for resources. Just how important is it from the teacher's perspective? Curriculum theorists have argued for and against primary science education (Jeans, 1992) but what importance do teachers place on it? The data show that, regardless of what happens in the classroom, teachers think that science education is very important. The mean value for this item was 8.4 (1.7). This was one of the highest mean values obtained in the study and the standard deviation was one of the lowest. However, without more information we can't know what this emphasis really means. For example, teachers could hardly help being aware of national and state government rhetoric about the importance of science in Australia's economic recovery. No doubt there is also a general realisation that the vast range of high-technology consumer products, advances in medical technology and the weapons of mass destruction are all related to science. Some teachers see science as a distinctive form of knowledge which contributes to the growth of rationality and is important for this reason. Some also see it as a valid means of educating children to understand the world, or, as a study of great interest to children.

Science, technology and society

The teachers were specifically asked for an opinion about the current emphasis on science, technology and society. The mean scale value was 7.7 (2.0) where 10 indicated total agreement. It is clear that even without detailed scientific knowledge teachers believe that interactions between science, technology and society are important and ought to be in the science education curriculum. Male teachers in mid-career were the most supportive group ($p=0.007$). When the question of how technology ought to be integrated into science education was asked there was a strong preference for teaching about 'how it works' rather than the physical principles underlying the technology. The mean value was 8.3 (1.8) where 10 was 'how it works'. Female teachers showed a significantly stronger ($p=0.002$) preference for the how it works approach. During informal discussion with teachers it was clear that the general concept of technology in science education had to with consumer technology such as bicycles, batteries, pumps, radios etc. Few teachers thought that primary science education should include practical problem-solving activities in which children are encouraged to devise technological solutions to real world problems (Fensham, 1981; Smith, 1983).

Specialisation

The sample was invited to comment on each of; specialist science teachers, specialist science rooms and on science education kits. The greatest number of comments concerned specialist science teachers and the least number was about the value of science kits. The mean value for the specialist science educator was 4.4 (3.2) and hence the concept was not well supported. The standard deviation in this case was considerably higher than for most other items in the study and the heterogeneity that it implies was supported by the diversity of comments. Arguments for specialist science education teachers included the value of having a person with detailed understanding of the goals of science education, knowledge of what science education content is worthwhile in the primary school, an awareness of health and safety issues, and a single teaching focus. Those who argued against specialists highlighted fears that specialists would remove some of the enjoyment that the generalist teacher derives from science education, miss opportunities for incidental learning and for integrating science education with the other curriculum areas and make it easier for the less confident or competent generalist teachers to ignore science education. The data are clear but it is interesting that there does not seem to be the same feeling about separate art rooms with specialist art teachers. Perhaps is just a matter of experience. Teachers have learnt that having a separate art room does not prevent them from art activities in the normal classroom. Presumably the compromise would be to have a specialist science teacher on the staff to support the science education program. The data suggest that if the ANZAAS (1992) recommendation that "a category of teachers termed 'science specialists' should be identified who are eligible to receive additional professional support and access to equipment and resources" were to be implemented a considerable effort would need to be made to prepare teachers for the innovation.

There was somewhat less diversity in the opinions expressed about specialist science rooms. The mean was 6.6 (3.0). '... also a separate science room would enable all classes in an elementary school to have a display area and set up experiments for others to try out'. Other teachers focussed on the negative effects 'Elementary science should often be integrated with other subjects - a separate science room would have negative effects'. Younger teachers tended to be stronger in support than older teachers but the significance of the difference is a matter of opinion ($p=0.056$). The value of specialist science teachers in the primary school is discussed in Gibbs (1989).

On the value of science kits with prepared lessons the mean response was 7.1 (2.2). The standard deviation indicates that the spread of opinion on this item was less than that for the other two items. Considered together these data are quite clear and lead to the generalisation that what is appropriate for one school at any given time may not be good for the same school at some other time or for some other school at any other time. Some schools would welcome a specialist science teacher and find a means of maximising her effect on the staff and students. Other schools would find it much more difficult to use a specialist and would require a good deal of preliminary consultation and negotiation. The generalisation highlights the inevitable tensions that are inherent in administering a large, complex system and at the same time allowing each component school the freedom to make critical program decisions. The introduction of simple, science education kits with prepared lessons would be a comparatively easy innovation and would have a fairly high degree of acceptance though experience suggests that maintenance would be a problem.

Preferred content
The topics that teachers are most confident about could be roughly classified into disciplines, principles and systems/natural phenomena. Some nominated geology and biology and there were references to astronomy and chemistry. Physics was never mentioned. This needs to be interpreted with care because as Gilbert (1991) points out, structuring science education around the science domains works against the unitary understanding that science educators want for their students. Some teachers named principles such as energy and force-motion and some listed systems/natural phenomena such as batteries and bulbs, weather, erosion, our planetary system and the various human systems (reproductive, skeletal etc). Plants was mentioned 155 times and energy, space and animals each occurred approximately 100 times. The human body was mentioned 18 times and the senses and insects mentioned less than 10 times each. Classification was mentioned twice. The data were interesting because of their diversity. The data show that there is virtually no common set of topics (content or process) that one might assume will be taught in primary science education. They also demonstrate what is already well known (De Bóo, 1989; Yates & Goodrum, 1990) and that is that primary teachers are most confident teaching topics from the biological sciences and least confident teaching topics from the physical sciences. The apparent preference for biological topics was also supported by the responses to an item which asked for an indication of preferred topic domains. The mean value was 5.7 (1.6) where 0 was 'only physical science' and 10 was 'only biological science'. One should note however that the only (biological) topic to be mentioned by about half the sample was plants. So, even within the biological sciences there is a rather narrow range of topics that one might expect will be taught with confidence. In a separate item teachers were asked to select from a list of 29 topics those that they thought ought to be in primary science education. Not surprisingly 94% selected plants. 90% included sound. Conservation, energy and water were each nominated by 87% of the sample. The only topics not nominated by at least three-quarters of the sample were flight (63%), volcanoes (72%) gases (64%), social responsibility (60%), transport (63%), electronics (67%), solutions (67%), plastics (59%), sex education (60%) and evolution (53%). A number of teachers noted that sex education was taught under health and/or physical education. Similarly, other topics appeared in curriculum areas other than science education.

With the exception of plants most of the topics that appeared in the confident list were listed by other teachers in the not confident list; energy, earth, space, electricity, electronics, magnetism, batteries and bulbs, astronomy, matter and physics and chemistry. The teacher who was not confident to teach 'Anything that needs chalk and talk which I can't explain using a hands on let's find out approach (some space concepts come into this category)' probably spoke for many of the teachers in this sample. The data also showed that processes are not normally thought of as content.

Confidence and competence
A teacher's effectiveness in the classroom is a function of her confidence and her intellectual competence. These are probably discrete but interactive variables. It is conceivable that a confident teacher would not necessarily have a sound knowledge base and it is equally conceivable that a competent teacher might not have the confidence for effective teacher-child interaction. In order to test this speculation teachers were asked to rate their personal confidence and competence in each of eight curriculum areas. The mean rating for science education competence was 6.5 and this was higher only than for music

education. For comparison, language education was 8.3 and music education was 4.8. The corresponding confidence ratings for science education and music education were 7.0 and 5.0 respectively. Using the means of the individual data the correlation coefficient was 0.813. This supports the hypothesis that confidence and competence are closely related and that changes in one may well result in changes in the other. If we can increase teacher competence we might increase their confidence and this might result in better primary science education. The high rank of mathematics education suggests that the teachers in this sample see themselves as more confident (8.35) and more competent (8.11) than has been suggested by the many critics of primary schooling. On the scale used for this item 10 indicated 'fully competent' and 'fully confident' respectively and so the data for science education are encouraging. Teachers are positive about their ability to be effective science educators. It is however a matter of concern that they are more positive about every other curriculum area except music education. Increasing experience was accompanied by perceptions of increasing competence in mathematics education ($p=0.054$) but not in science education ($p=0.249$). Experience and confidence were positively associated for mathematics education ($p=0.001$) but not for science education ($p=0.697$). Experience rather than age was chosen as the relevant variable although the two are highly correlated (0.806). For science education, male teachers rated their confidence significantly higher ($p=0.013$) than female teachers. The data show that the concept of a generalist primary teacher equally competent and confident in all curriculum areas has rather weak support. Teachers were asked to select possible causes of low confidence; Table 2 presents the findings.

TABLE 2
REASONS FOR LOW CONFIDENCE

Lack of knowledge	261
Inadequate materials	194
Organising materials	165
Other	42
Safety problems	44
School policies	8

The largest single contributor to lack of teacher-confidence is clearly lack of knowledge. Presumably increasing teacher knowledge would increase teacher-confidence. The other major contributor has to do with difficulties of obtaining and organising materials. The two main reasons given in the 'other' category had to do with views that science education was irrelevant to primary schooling and that the teacher was simply not enthusiastic enough to teach science education effectively. These were minority views and were the sole cause of lack of confidence in one case only.

The gender dimension

The gender dimension of science education in the post-primary sector has been the subject of considerable debate (Johnston, 1984; Hildebrand, 1989; Martinez, 1992) with a number of writers suggesting that there should be separate science education classes and maybe even separate science content - based on the notion that the relevance of some topics in science education is gender-dependent (Smail, Whyte & Kelly, 1982; Taber, 1991). For those who are persuaded that this is necessary the issue arises of when boys and girls ought to separated for science education. As with most educational research very few generalisations actually hold good. Lock (1992) has shown that for some practical skills such as planning, observing and reporting there are no significant gender differences. Teachers in the present sample were asked to comment on the notion of separate education classes for boys and girls. Although a number of teachers recognised arguments for separation in post-primary science, around 88% of the sample were strongly opposed to the idea for primary schools. Opposition was expressed in strong terms; 'rubbish', 'sexist', 'abhorrent' and 'garbage' were among the terms used. Ten percent however made a variety of supportive comments some of which would no doubt be shared by the 90% who were opposed. For example, a number of teachers made the point that all-girl groups could sometimes be quite appropriate provided that there was whole class discussion and follow-up. Those who made such comments often mentioned their personal experience with Lego. There was only one teacher who gave unreserved support and argued that it helped develop confidence in girls in what is commonly seen as a male domain. Others who supported the notion saw the benefits of having smaller classes to work with. The counter argument was that more supervision would be required.

CONCLUSION

Though there is need to be cautious in generalising the results of this study to Australian primary teachers the coincidence of findings with those of a number of other studies suggest that the conclusions drawn from the data are generalizable. About half the sample responded to an invitation to add any other thoughts that they had about the state of science education at primary level. The responses were varied in form but reflected a number of underlying issues. There was a general feeling that science education has a long way to go before it could stand alongside language and mathematics in matters of time and resources allocated, teacher knowledge, confidence and enthusiasm, and in matters of quality. Many thought that science was inherently exciting for teachers and pupils and that what they, personally, were doing was inadequate. Nobody could read through the comments and not come to the conclusion that teachers genuinely wanted to do the best job that they possibly could. It was clear that collectively the teachers tended to undervalue their own science knowledge, but it is also clear that very few individual teachers have the knowledge-base needed to construct an interesting, developmental science education program. Funding constraints were mentioned over and over again; funding for time release, for equipment and for in-service education. There is the possibility that some teachers over-emphasise the funding required for good science education and a lot of work is needed with those teachers who see science as only technical equipment, chemicals and experiments. It is great to conduct science days or science fairs and have, for example, high school staff conduct activities using expensive equipment and one would want to encourage this but an exciting primary science education program can be taught with quite low cost equipment. Nevertheless some funding is required and most teachers are not getting even the small amount of money needed for recurrent costs.

A significant number of teachers said that they worked with an integrated curriculum and science education was part of this. However, nobody said that science education was the core of the integrated curriculum. There is no reason why science education shouldn't be part of integrated curricula but presumably one would still need to set science education objectives in order to be able to monitor the degree to which the science education component is systematic and develop-mental and not haphazard and repetitive. Setting objectives implies that the teacher, and perhaps the school, will have an overall plan for achievement in science education.

There was some evidence that teachers are aware of arguments about the role of women in science and the need to select curriculum content and develop teaching strategies that will ensure that girls have at least equal opportunities to learn. Similarly there was recognition of the science, technology and society perspective. The responses and comments to the questionnaire used in this study suggest that these contextual issues are not seen as very important in the primary school. Whether or not we can become a clever country simply by having more scientists and technologists remains to be seen. However, if we are to have even a threshold level of scientific literacy we need to break the cycle as early as possible. Primary school children who have completed a systematic and interesting science education will consider taking science education in the post-primary school and beyond and some of these will eventually become teachers (Carter & Carré, 1991)

There are many good examples of individual initiatives in science education but these are likely to remain isolated cases unless Australia addresses the issues raised by the teachers in this study.

REFERENCES

ANZAAS, (1992). Science in primary schools. Is it up to scratch?. Address to the March meeting of the Victorian division of the Australian and New Zealand Association for the Advancement of Science. Newsletter, 12 April 1992.

Blake, A.J.D. (1977). The case for science in the elementary curriculum: Will the true progressivism please stand up. The Australian Science Teachers Journal. 23(3), 13-18.

Carter, D.S.G. & Carre, C. (1991). Research report: Gender differences in primary teachers' self-estimates of their competence to teach National Curriculum Science. Australian Educational Researcher 18(2), 31-41.

Charron, E. (1991). Towards a social contexts frame of reference for science education research. Journal of Research in Science Teaching. 28(7), 609-618.

Dawson, C. (1991). Beginning science teaching. Melbourne, Longman Cheshire.

De Bóo, M. (1989). The science background of elementary teachers. School Science Review. 70(252), 125-127.

Fensham, P. (1981). Heads, hearts and hands - future alternatives for science education. The Australian Science Teachers Journal. 27(1), 53-60.

Gibbs, A.F. (1989). Elementary science: A time for action. The Mendelian. 7, 7- 23.

Gilbert, S.W. (1991). Model building and a definition of science. Journal of Research in Science Teaching. 28(1), 73-79.

Hildebrand, G. (1989). Creating a gender-inclusive science curriculum. The Australian Science Teachers Journal. 35(3), 7-16.

Hurd, P. DeH. (1990). Change and challenge in science education. Journal of Research in Science Teaching. 27(5), 413-414.

Jeans, B. (1992). New directions in the training of elementary science teachers. Paper presented to the annual conference of the Association for Teacher Education in Europe. Lahti, Finland

Jeans, B. & Farnsworth, I. (1991). Competence and confidence in the teaching of elementary science. Paper presented to the 1991 Conference of the Australia New Zealand Association for the Advancement of Science. Adelaide, Australia.

Johnston, S. (1984). Girls need a science education too. The Australian Science Teachers Journal. 30(2)pp. 18-23.

Lock, R. (1992). Gender and practical skill performance in science. Journal of Research in Science Teaching. 29(3), 227-241.

Marsh, C., Day, C., Hannay, L. & McCutcheon, G. (1990). Reconceptualisating school-based curriculum development. Basingstoke, England, Falmer Press.

Martinez, M.E. (1992). Interest enhancements to science experiments: Interactions with student gender. Journal of Research in Science Teaching. 29(2), 167-177.

Shymansky, N.A., Yore, L.D. & Good, R. (1991). Elementary school teachers' beliefs about and perceptions of elementary school science, science reading, science textbooks, and supportive instructional factors. Journal of Research in Science Teaching. 28(5), 437-454.

Smail, B., Whyte, J. & Kelly, A. (1982). Girls into science and technology: the first two years. School Science Review. June, 620-630.

Smith, H. (1983). Science education: Where to now? The Australian Science Teachers Journal. 29(1), 25-26.

Smith, H. (1985). What's your science department's curriculum policy? The Australian Science Teachers Journal. 31(2), 45-48.

Taber, K.S. (1991). Gender differences in science preferences on starting secondary school. Research in Science & Technological Education. 9(2), 245-251.

Yates, S. & Goodrum, D. (1990). How confident are primary school teaching in teaching science? Research in Science Education. 20, 300-305.

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SCHOOL-BASED ASSESSMENT OF PRACTICAL COMPETENCE IN SCIENCE: SOME ISSUES FROM ENGLISH EXPERIENCE

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ABSTRACT

Teacher-conducted assessments of practical skills are a compulsory component of GCSE examinations in science in England and Wales. The paper presents some of the findings of a research project that investigated this aspect of a science teacher's work. The project was concerned principally with the ways in which science teachers interpreted and operationalised the policy decision of central government and examination boards that teachers assume responsibility for the internal assessment of the practical competence ofpupils aged 14-16 preparing for GCSE examinations in science.

INTRODUCTION

Science, which may be taught as separate disciplines, is a compulsory component of the national curriculum in England and Wales. Pupils' work in science at Key Stage 4 (= ages 15/16 or years 10 and 11) is assessed by the General Certificate of Secondary Education examination (GCSE). All GCSE science examinations incorporate a school-based assessment of pupils' practical competence, conducted by teachers in accordance with the requirements of the examination board. In England and Wales, there are five examination boards and the differences in their requirements for assessing pupils' practical competence are currently substantial, not least in the proportion of the overall marks to be awarded on the basis of school-based assessment. Although a central government decision that this proportion cannot, after 1994, exceed 30% will have a significant impact on some GCSE assessments, teachers will still be required to interpret the assessment framework laid down by an examination board and to develop and implement, at school level, an assessment policy to generate the required marks.

This paper is derived from a research project that sought to explore the origins of recent national policy for the assessment of practical skills in years 10 and 11, to survey contemporary assessment policy and practice for GCSE in schools, and to investigate the wider impact of the assessment activity in terms of its diagnostic value, its integration into the science curriculum proper and any changes that it may have precipitated in science education in the earlier years of secondary education. The project also addressed the determinants of assessment policy for practical work at national, regional and local level. The overall findings of the project, therefore, contribute to an understanding of the relationships between policy and practice in one aspect of science education, namely the school-based assessment by teachers of their pupils' practical competence within the framework of a national examination in years 10 and 11. This paper indicates some of the findings of the project. More detailed outcomes are the subject of separate papers (e.g. Buchan, 1992; Buchan & Jenkins, 1992; Buchan & Welford, 1993) and, in due course, of a book.

RESEARCH METHOD

Most of the information about the recent origins of policy for the internal assessment of practical work was obtained from the published literature since access to the relevant central government working papers was not possible. Practice and policy at school level was explored in four ways:

- the collection and scrutiny of written documentation produced by schools describing their assessment procedures;
- structured interviews of those involved in, and/or affected by, assessment policy and practice, commonly science teachers, heads of department, technicians, pupils, members of staff with curriculum or particular pastoral responsibilities, and local education authority advisors. The interview schedules were used in a sample of ten schools, chosen to reflect differences in catchment area, age range (e.g. 11-18, 11-16), governance (local authority/independent), and science course/syllabus followed;
- classroom observation of practical assessments carried out by teachers, using an observation schedule which focused attention on the content and administration of the task to be used for assessment, the mode of organisation, the classroom interaction and the data gathering procedures.
- a questionnaire, developed and tried out in local schools before being sent by the National Foundation for Educational Research to a stratified, 10% sample of all schools in England and Wales early in 1991. This produced 500 usable returns (66%). The four sections of the questionnaire sought information about the school and the science department and about the curriculum and assessment in years 7 to 9 and in years 10 and 11. (Data from the questionnaire are not discussed in this paper).

SOME RESEARCH FINDINGS

The immediate origin of policy for the internal assessment of practical work in years 10 and 11. The principal source of official policy for the assessment of GCSE science was the statement of the National Criteria for Science which required the assessment of course work and specified the relative weighting to be given to it (DES, 1985). There seems to have been no debate about the nature of this course work. As far as science was concerned, it was identified with the assessment of practical and experimental skills, largely by the examination boards responsible for the conduct of GCSE examinations. This identification was consolidated by an inservice guide for teachers produced by the Secondary Examinations Council (1986) in collaboration with the Open University and made available to all secondary schools. This claimed that "the assessment of coursework ... can provide the best evidence of candidates' achievements in certain process areas of science" (p.52) and it offered a paradigmatic account of assessment practice in a naturalistic laboratory/classroom setting. The document also made clear that "formal practical tests, unsupported by course work, would not normally be regarded as acceptable" (p.54).This identification of course work with practical work consolidated and legitimised existing pedagogic practices and traditions in secondary school science teaching. More particularly, it confirmed that pupils' practical competence in science was to be seen in terms of skills, an interpretation that has proved to be of seminal importance.

As Buchan (1992) has shown, the examination groups, working within this national policy framework, generated a variety of GCSE science syllabuses and assessment requirements. These groups, therefore, both mediated policy in this field and developed and promulgated policies of their own. The outcome was a set of procedures to be followed by science teachers in assessing the skill-defined, practical competence of their pupils preparing for GCSE examinations. However, the research shows that these procedures, seemingly secure enough to permit reliable and valid assessments, allow teachers and science departments considerable discretion in interpretation. The evidence is that this discretion is exercised in significantly different ways, thus permitting individual science teachers, science departments or schools an active role in policy formation and realisation. In addition, the evidence suggests that this discretion has led to substantial, but largely unacknowledged, technical and other difficulties in school-based assessment of practical work as a component of a national examination in science.

Policy and practice at school level

* Choosing a GCSE syllabus

Given the diversity of the examining groups' approaches to school-based assessment of practical work (Buchan, 1992), it is not surprising that some teachers 'shopped around' for the approach which, in their judgement, would best serve the needs of their pupils. Such needs, not unreasonably, were seen as closely associated, if not identical, with success in the GCSE examination. The participant school in the study which served the most socially disadvantaged catchment area chose a GCSE syllabus that allowed up to 40% of the overall marks to be awarded on the basis of teacher-based assessments of practical skills. The reason for selecting this GCSE syllabus was the belief that many of the pupils had language difficulties and/or were below average in ability. The 40% option allowed the school to devise assessment strategies did not disadvantage these pupils or, at least, did not add to those difficulties they would encounter in the written component of the examination. The claim that practical work is both of fundamental importance to science education and more suitable for the less able and/or those with language difficulties presents problems that, in this school at least, were not addressed.

* Assessment instruments and tasks

As far as the development of assessment instruments is concerned, the research identified two broad strategies. The first involved a coordinated science department initiative that led to the production of one or more 'assessment packs', used by teachers on an 'off-the-shelf' basis. The other strategy allowed science teachers to develop and use their own assessment instruments, an approach that, superficially at least, seems easier to reconcile with the idea that assessment should be an integral part of teaching. The first of these two strategies was less common than the second, with teachers gradually acquiring tried and tested exercises that were sometimes pooled and evaluated collectively. Both strategies, however, presented problems for the technical dimensions of assessment. A central assessment bank was readily seen as ensuring 'fairness', a quality rated highly by the teachers and sometimes seemingly equated with reliability. In contrast, the ad hoc development of assessment instruments, even when coupled with 'agreement meetings', led to a diversity which, in some cases, had been the subject of criticism by the examination board. The practical tasks used for assessment purposes generally derived from the routines of school science teaching. Almost without exception, the assessment procedure involved a worksheet and depended upon a pupil's written output for evidence. Teacher observation of practical competence was focused on tests of 'measurement skills'. Investigative, holistic assessments as commended in the official advice to teachers were noteworthy by their absence.

* The organisation of practical assessments

Several organisational strategies were evident among the ten schools studied. One operated a 'skills week', during which large numbers of pupils would have their practical skills assessed. Another organised timetabled practical examinations and a third, which had developed its own bank of assessment items, arranged that assessments were undertaken by all pupils at the same point within standardised modules. Most of the schools, however, operated systems that were more flexible in both chronological and organisational terms. The most common format can be conveniently described as 'examination conditions', i.e. pupils worked separately and in silence. Some relaxation of this was found in several schools but only very rarely to the point at which the situation might reasonably be described as a normal class practical. Assessment in groups took place in only three schools and then only infrequently. The decision by one school that all practical assessments should be made under examination conditions, coupled with a strict insistence that all work be guaranteed as a pupil's own, posed some formidable organisational problems that led to some hostility among staff. In some cases, a teacher observed individual pupils for assessment purposes while two thirds of the class were engaged in an unrelated activity in the same room or elsewhere. The procedure adopted for individual assessments was determined mainly by the requirements of the particular examination for which the pupils were being prepared. One well-known (biology) syllabus specified no less than thirty two individual 'skills' and this often precipitated a procedure whereby pupils were repeatedly assessed at particular skills until they were judged successful. Several teachers were unhappy at this tactic, claiming it devalued the assessment process. A recurrent theme in all cases was the need to be 'fair' to the pupils. Fairness had both a procedural and a judgemental component. The former included teachers' willingness to organise 'repeat' practical sessions, often at lunchtime, for pupils who had been absent when the original assessment had been made. It was also taken to refer to consistency in marking and to following scrupulously the procedures laid down by the examination boards. The judgemental component of fairness was much more problematic if it included, as it often did, the repetition of an assessment and the subsequent choice of the best score from among those thus generated. Although this practice was permitted by the regulations of the examination boards, it was exercised at the discretion of individual teachers. The range of practice in the schools studied suggests that science teachers lack an agreed and articulated understanding of assessment as part of their professional repertoire.

* Pedagogy

It has already been noted that the context in which the science teachers commonly conducted the practical assessments of their pupils was that of a formal examination or test. However, this did not preclude helping pupils with their assessments. Indeed, 'help sheets' were commonly available, although their use normally led to the deduction or limitation of marks. The availability of this assistance affected the relationships between the teacher and his/her pupils. If a pupil knew the consequences of asking for a help sheet, there was naturally some reluctance to do so. Conversely, if these consequences were not known to the pupil (a less likely situation), then it was the teacher who faced the difficult decision whether or not to take an action that would in some way limit the marks available to the pupil. While this can be regarded as an exercise of 'professional judgement' there is little evidence that this judgement is exercised consistently within an explicit framework common to all schools. The teachers themselves justified offering help by invoking, as on other occasions, the need to be 'fair' to pupils. Underpinning the teachers' actions, however, is a tension between their roles as teacher and examiner, a tension which some tried to accommodate by describing themselves as 'facilitators' who merely helped pupils to achieve at their highest level in an assessment exercise. This tension was also evident in the failure to use the outcomes of individual assessments for diagnostic purposes. Teachers frequently said that the assessment results disappeared into the filing cabinet, although there was often some feedback to a class as a whole when pupils were told the outcomes of the assessment. This was not possible when, as several teachers confessed, work was not marked until long after an assessment had been completed. Pupils themselves appeared to value such feedback as they received and in cases where several assessments of individual 'skills' were undertaken, pupils themselves occasionally used the implicit profiles of attainment for their own purposes. It would, however, be a mistake to see this as a form of diagnostic assessment. A more appropriate term would be 'notching up the skills'. At the centre of the teacher-examiner issue are questions which are essentially to do with validity. How did what was assessed as practical work relate both to what science teachers would normally do and to their rationale for doing it? Many teachers were clear that the requirement to undertake assessments had compelled them to think more carefully about the purpose of the practical activities in which they engaged pupils. This post hoc search for a rationale for a supposedly key element in school science education is of some interest but it seems not to have been recognised by the science teachers themselves. Beyond this (and occasionally in apparent contradiction of it) the teachers were unwilling to admit that they had altered their approach as a result of the requirement to assess the practical competence of their pupils. The rationales offered for laboratory work were not new: it motivated children, science is a 'practical subject', it helped children think scientifically, etc. The last of these was commonly cast in the fashionable terms of introducing children to the 'processes of science'. One teacher, apparently without intending irony, described herself as 'a true believer in the processes of science'. Others appeared surprised that the question 'Why undertake practical work?' should even be asked. Despite the overwhelming sense of continuity with past practice, the discourse which teachers used to discuss practical assessment had novel characteristics. Its common currency was the language of 'skill'. The use of expressions involving the word skill was idiosyncratic, even bizarre, and is one of the most striking features of the study. Thus, pupils were said to 'have' a skill, to be 'given' a skill, to have 'done' a skill, or, in one case, to have had a skill 'taken away'. There was even a reference to 'paper skills'. This usage is probably not so much a consciously deployed notion of homogenized, transferable and deproblematised skills, as a discourse and practice impregnated with the procedures and the transmuted and re-situated language of the examination boards. Nonetheless, the linguistic dimensions of the internal assessment of practical work deserve further study.

DISCUSSION

School-based assessment of pupils' practical competence in science at GCSE level is a consequence of a policy decision by central government. The research reported in outline above suggests that the greater role in originating and sustaining policy in this area lies, not with central government, but with the schools, examination boards, professional associations and the science teachers themselves. 'Policy' is delocalised and differentiated, and its 'implementation' a matter of complex interaction of rhetoric and rationale with internal and external constraints. This perspective upon science education policy suggests a substantial research agenda and its wider implications, e.g. for the introduction of a national curriculum in England and Wales, are significant. More particularly, the research reveals some significant gaps between what might be called the 'policy for practical assessment' and what actually happens in schools. Assessment of practical work in naturalistic settings is very rare, open-ended investigations are few, the assessment instruments are generally focused, routinized, and heavily mediated by teachers' perceptions of pupils' literacy, and assessments are usually undertaken under examination conditions. All of this might be described as a summary of 'standard practice' in the assessment of practical work for the purposes of the GCSE examination. Standard practice, however, is not necessarily good practice and the orthodoxy that it represents may undermine critical reflection and discourage the independent thought and action necessary for innovation. The research project, however, was not centrally concerned with this issue. Rather, the focus was on how forms of policy and practice are sustained and how the processes involved can be conceptualised and improved. Work on these aspects of the research is continuing. In particular, attention is being given to examining the historical and institutional determinants of the work of individual science teachers and to exploring how teachers' 'professional judgement' might be given a stronger theoretical and operational underpinning.

REFERENCES

Buchan, A.S. (1992). Practical assessment in GCSE Science: the diversity of examination group practices. School Science Review, 73, (265) 19-28.

Buchan, A.S. & Jenkins, E.W. (1992) The internal assessment of practical skills in science in England and Wales, 1960-1991: some issues in historical perspective. International Journal of Science Education, 14, (4) 367-380.

Buchan, A.S. & Welford, A.G. (submitted for publication). Policy into Practice: 1, the organisational, financial and curricular setting of practical assessment in science at GCSE.

Buchan, A.S. & Welford, A.G. (submitted for publication). Policy into Practice: 2, the effects of practical assessment on the teaching of science.

DES (1985). General Certificate of Secondary Education. The National Criteria: Science. London: HMSO.

Secondary Examinations Council (1986). Science: GCSE. A guide for teachers. Milton Keynes: Open University Press.

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TEACHERS' PERCEPTIONS OF TECHNOLOGY EDUCATION: IMPLICATIONS FOR CURRICULUM INNOVATION

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ABSTRACT

This paper describes research into teachers' perceptions of technology education carried out as part of the Learning in Technology Education Project. Thirty primary and secondary school teachers were interviewed. Secondary teachers interpreted technology education in terms of their subject subcultures as did some primary teachers. The primary teachers were also influenced by current initiatives, outside school interests and teaching programs.

INTRODUCTION

This paper reports on research into teachers' perceptions of technology education carried out as part of the Learning in Technology Education Project. Based at the Centre for Science and Mathematics Education Research at the University of Waikato, this is a two year project funded by the New Zealand Ministry of Education.

Technology education in New Zealand is now a major focus of discussion and has been defined as an essential learning area. A curriculum statement is being prepared in this area along with English, Mathematics and Science (Ministry of Education, 1991). Previously, technology education has not had a separate curriculum statement.

Teaching and learning at the school level is often bound up with the initiation and the socialisation of teachers into subject subcultural settings (Goodson, 1985). These subcultures, according to Paechter (1991), represent reasonably consistent views about the role of the teacher, the nature of their subject, the way it should be taught and expectations of the students' learning. Goodson (1991) suggests that to understand teacher and curriculum development and to tailor it accordingly we need to know a great deal more about teachers' priorities. He notes that many of these priorities can only be found by examining in detail past influences on the teacher. Paechter (1991) also points out that the teachers' beliefs about what was important for students to learn in their existing subject areas, such as craft design and technology, home economics, art, were transferred to technology education. In Sweden, Lindblad (1990) found that primary school teachers in responding to developing a new technology curriculum formulated classroom experiences based on their past experiences. For example, Art teachers made the curriculum into a design course and science teachers made it into a laboratory course.

A further major dimension to teachers' perceptions of a new subject is their response to change. As Claxton and Carr (1992) note, change enacted without commitment may be implemented in a rigid mechanical way that follows the letter of the innovation but fails to convey the spirit. In a climate where teachers felt pressure from many different directions, any prescription for change may not feel like a solution but can be viewed as a further problem. It is therefore important when thinking about a new curriculum area to take into account teachers' perceptions of the new area and to think about how these perceptions will influence new curriculum formulation and implementation.

In thinking about innovation, then, the subjective realities of teachers must be taken into account. Fullan (1982) suggests that unsuccessful innovations have been based on models which do not take into account these realities, including the teachers' views about their subject area and their views of learning. Fullan further suggests that change will only come about if the balance between rewards and costs are acceptable to teachers.

METHOD

Three schools (one primary, one intermediate, one secondary) which agreed to take part in the research during the two years of the project were the source of the teachers whose perceptions were explored. Thirty teachers (16 primary and 14 secondary) were interviewed. These teachers ranged in experience (2-30 years teaching), level of responsibility (assistant teacher to deputy principal) and, particularly in the secondary school, subject specialities. The teachers were interviewed individually for between 15 and 45 minutes. These interviews were audio-taped, transcribed and analysed.

A schedule of the areas to be explored was prepared but the interviews were free ranging. Teachers were first asked about their career history and then their initial response when they heard about technology education being announced as a new subject area. The questions then explored what technology education meant at a school and individual subject level. Later they were asked about the contribution of existing practice to technology education, how they saw technology fitting into a school programme and the management of this subject. The interviews also explored what students should be learning and how a subject like technology education should be taught.

ANALYSIS OF INTERVIEWS

Examining teachers' perceptions of technology education revealed their difficulty in talking about a subject or discipline that did not yet exist. Many teachers used their past experiences in and out of school to construct a perception of technology education.

Secondary teachers' perceptions of technology education

Secondary teachers talked about technology in terms of the subjects that they teach. They interpreted technology education in terms of their subject area or in terms of the discipline in which they were trained. Included in these perceptions were teachers' views about what should be taught in technology, what students should learn, and the place of technology education in the school. When teachers were asked what they thought students should be learning in technology education the reply was often in terms of their existing subject areas.

Secondary school teachers' subcultures

The science teachers all saw technology education in terms of applications of science. In terms of teaching, technology was perceived to be a vehicle for teaching science, frequently as something extra to the conceptual development in science. There was concern expressed about non-science teachers incorporating the scientific aspects of technology into their lessons. The following comment reflects the views of all of the science teachers:

> It [technology] would fit best in science . . . it depends what aspects of technology you are going to explore and what for. . . I try to as an application If it is from a sociological point of view it is better to explore it in social studies . . . but from the scientific aspect it would be better through science rather than having social studies teachers trying to teach the science of technology. [Science teacher]

Social studies teachers emphasised the social aspects of technology particularly in terms of awareness and the human aspects of technology. They wanted students to develop skills to cope with life in the future and to become aware of technology to cope with future changes.

> The purpose of education in technology is the skills which are necessary for students to take their place in a technological society. To give them the understanding necessary to use and not abuse technology and a technological approach to life. [Social Studies teacher]

English teachers associated technology education with media studies, techniques used in journalism and drama.

> Doing drama really teaches things about problem solving, the kids have got to find an audience, find a market, got to advertise . . . how much to charge them . . . designing and creating props. [English teacher]

The Accounting teacher talked about students' learning in technology education in terms of using computers and awareness of technology in our lives. Economics teachers emphasized concepts related to resources.

> In terms of my own subject it would be in terms of computer aided accounting. Economics is concerned with resources and how technology might improve those resources. [Economics and Accounting teacher]

The emphasis of the technical teachers at the secondary school was on 'design and make' and using a variety of skills to realise practical outcomes.

> Students should learn how things work and operate, how materials behave some this way and how you see tools to shape things to make things and eventually come out with some practical outcome. There is knowledge, there is designing and there is some practical outcome. [Technical teacher]

Thus it can be seen that at the secondary school level the subjects that are taught by the teachers influence what they think technology education is about and what the students should be learning. These subject subcultures also influence the teacher in thinking about what the students might already be capable of in terms of technology education. The teachers in the secondary school also lacked knowledge about what is taught in other subject areas that might contribute to technology education. In many of the discussions the teachers were concerned that the aspects of technology education that were already being taught in their subject areas might be removed when this new subject called technology was introduced. No one teacher had a broad view of technology education and their view was restricted to the subject within which they were trained and taught. It became apparent that many of the secondary school teachers felt that, in terms of their current perceptions of technology education, they were already incorporating technology in their subjects. This was particularly true of the social studies and technical teachers who all thought that they had already incorporated technology into their subjects' existing structure. Science teachers while not necessarily incorporating as much technology as they may like, nevertheless thought that technology was being covered in science.

Views on approaches to technology education

A cross-curricular approach was the only mechanism that teachers mentioned for the introduction of technology education, that is apart from very minimal change.

> I think in the junior [secondary] school it would be best if departments worked together rather than in isolated units rather than having a new separate subject called technology. . . . there is a whole bulk of scientific theory that students should know. The students need to experiment . . . students need to know how materials work, why they behave like that and why . . . the social aspects can come through social studies. [Technical teacher]

It may be that they were not aware of other approaches, or that a cross-curricular approach would keep many of the existing structures in place and require the smallest amount of change. Teachers were aware of the difficulty of working with other departments and felt that there had to be a commitment from the senior management in the school to the idea. Although some teachers felt they could work on an individual basis with other teachers to integrate students learning they were unsure about how integration would work at the departmental level. Teacher collaboration was mentioned but apart from a cross-curricular approach other modifications to existing educational settings were not mentioned. It may be that teachers are not aware of other approaches and these should be highlighted and debated publicly.

Primary teachers' perceptions of technology education

The primary teachers were not locked into their subject subcultures, although they were influenced by their past experiences, both in and out of teaching.

In both the primary and the intermediate school teachers were trying to integrate computers into their classroom. In the primary school there was one computer per class and at the intermediate school there were computers in a resource area. Many of the teachers at the primary and intermediate school viewed technology in terms of computers. This meant using computers or other technology to solve problems. For example, as stated by one teacher, "not using pen or paper but using computers to solve problems". Many intermediate teachers saw technology education as students "using" technology as part of their learning experiences and this was, in the main, using computers.

> We use technology across the curriculum for example some of the maths that we do can be done on the computer or on calculators. So technology is coming into the maths program. Word Processors are coming into language.

Another aspect of technology education mentioned by the teachers was for the students to find out how things work. Teachers also mentioned problem solving in relation to finding out how things work.

> Using examples of technology as a way of finding out how things work.

When talking about technology, teachers have mentioned problem solving both in the context of using computers and finding out how things work. Technology is seen as a mechanism for solving a problem or as a vehicle for approaching a particular type of problem solving, that is, finding out how things work.

A group of teachers who did not emphasise computers in their perceptions of technology education emphasised the links between science and technology. Technology was seen to be closely linked to science and the teachers were trying to make the science courses more relevant by including technology. Some of these teachers had attended courses which emphasised this approach.

> Technology is about science they go together. Technology is the practical awareness or help with science - make things to understand science things. Technology goes along with science. Children are interested in how things work . . . it would involve using various apparatus or going into more depth in their own way. Children in this school have very enquiring minds and want to find out how things work.

Although teachers in the primary schools teach a range of subjects they appear to take a special interest in particular areas. This is apparent when one group of teachers places an emphasis on computers and technology education while others talk about the close relationship between science and technology.

At the secondary school level social studies teachers predominantly emphasised the awareness and social aspects of technology. Many primary school teachers also placed importance on students being aware of technology and being confident with it. Again this was mainly in terms of new technology and computers.

> It's keeping up with technology and making children familiar with them and not afraid of them.

The introduction of technology education

In primary schools, teachers often take an integrated approach to most of their teaching, several stated that they did not want to see technology introduced as a separate subject.

> Its integrated into our lives so we need to integrate it into our teaching . . . . we need a stimulating technological environment.

Primary school teachers were generally positive about the introduction of technology, even though they had different perceptions of what it might be. They emphasised ownership, improved learning, student interest and flexibility as important factors in considering the uptake of technology education.

> A technology national curriculum subject would provide us with a challenge if we were allowed to integrate it into our programme. We must be allowed to develop ownership of it.
> We are willing to try things . . . if it makes learning more exciting and children learn more then it has to be a good thing.

Some teachers may not be aware that they have already introduced aspects of technology into their existing teaching and learning programmes. The comments of one teacher when asked about some children's work which was displayed on the wall, illustrate a dawning awareness of this:

> . . . . so it [technology] might include something like we are trying to do to construct bridges and see what they come up with - I never thought of it as technology education just thought of it as problem solving..

Influence of past experiences on primary and secondary teachers' perceptions
Teachers' perceptions of technology education were closely linked with their life experiences.

Outside interests: Music has moved towards the use of electronics and computing and this influenced two teachers Both were music teachers in the primary school. As the teachers stated:

> I am involved in technology when doing my music. When I think of music I think of computers, drum machines. . . . I mainly use the 'hi-tech' end in my teaching. Children doing programming on the drum machine, using recording equipment.

School responsibilities: Technology, for the teacher in-charge of the library, was retrieving information by using computers and this tended to dominate her thinking about technology education in schools. As she says:

> Everything is technology in terms of helping us . . . to help everybody . . . technology to help in learning . . moving learning to 1990 e.g. the library we hope to have all resources on the computer e.g. searching for something on Vikings.

Teachers who had invested time developing computer awareness and integrating computers into their classroom focussed on information technology.

> I think we are already doing a lot of technology education in schools like using computers and hypercard and I think we are using technology for problem solving and for children to work cooperatively together.

The influence of pre-service training: Courses and activities undertaken during teacher training had an influence on perceptions of technology education. During training there was a course called educational technology which consisted of learning about technology used for teaching. This obviously influenced some to think about technology as being the use of technical equipment within their teaching.

> I did a course in educational technology such as videos and OHPs.

For other teachers the approach to the teaching and learning of science influenced how they viewed technology education and its close relationship to science.

> One thing was the interactive science that I did at [Teachers'] college . . . we had to go to the school and do batteries and bulbs and it was electricity and I knew nothing about electricity and all I knew about science was that I loathed it at high school. Students had to find out solutions to real problems using batteries and bulbs . . . I guess that was technology. . . . we went into the interactive science I realised it wasn't just science it was a whole way of thinking and doing.

The influence of in-service training: In talking about how they developed their views of technology education several teachers mentioned courses that they had attended which they perceived to have a technological focus.

> I've been on a course . . . . That is technology - the use of science to solve problems around you. The course also promoted technology in school, particularly electricity with the junior classes. You could only justify its use in terms of a teaching tool.

Extended professional development programmes also influenced teachers in their perceptions of technology education. Some science teachers used technology as an extension for more able students and had attended courses which emphasised this approach. They were working with more able students and developing accelerate courses with an emphasis on the applications of science. This then led to a view of technology education being for the more able science student and technology being the applications of science. Some teachers particularly at the intermediate school had attended courses such as educational computing and they saw this as being technology education. Two more senior teachers had taken courses in educational administration where one of the emphases had been on using computers to solve administrative problems, such as using spread sheets for school accounting procedures.

The influence of being a beginning teacher: Beginning teachers were trying to come to terms with their subject areas and issues such as technology education were seen as an extra.

> . . . basically in my first three years of teaching I have been trying to get everything together and tend to concentrate on the basics and then will start adding technology into it.

The problem of change: Some of the teachers were feeling threatened by further change, because technology education has not been defined; there was a feeling of more being imposed upon them when they felt they were just coming to terms with past changes. These teachers emphasised the technology component in other subjects or just concentrated on students going to the computer lab. Technology was seen as an extra to their teaching.

The influence of previous work experience: Not all teachers had taken the direct route to teaching coming from careers outside teaching. The use of technology in those careers influenced those teachers' perceptions of technology education. One teacher had been a secretary before returning to university and undertaking teacher training. In her view technology education was to use equipment such as word processors to make life easier.

> I guess I think of it as using computers and equipment to make the job easier. Like for example in offices now word processors are part of life and we should be making students aware of that.

Another teacher associated technology with the 'hi-tech' that she had seen when she worked as an administrator in industry. When talking about technology she emphasises this and suggests that technology should be undertaken at polytechnics.

> The place for advanced technology studies is probably at the Poly-tech where there is money and resources - there is already an accepted relationship between education and the community.

A science teacher was influenced by his past career as an engineer and a career in sales. When he was a sales manager he was concerned with learning about the specifications and scientific theory behind the technology. His perceptions of technology education were dominated by applications of science to technology. He perceived technology as using difficult scientific concepts and hence these might not be accessible to the students. His views of technology education were also influenced by the constraints he saw himself working under in the classroom. Two teachers who had previously worked as research scientists were also concerned about the difficult scientific concepts involved in technology. They also linked technology with the applications of science.

> Some of the science concepts in the technology you are investigating can be quite complicated. Bringing it down to the level of the students can be a problem.

A techni-craft teacher at the intermediate school was influenced by his career as a joiner and felt that it was important for students to be taught the skills in woodwork. Throughout the interview he emphasised how important skills were in his past career.

> I want to stress the importance of manual skills - I see our job as being to teach the basic manual skills. I don't know what all the fuss is about it has always been there and the skills I needed I teach them. I now have had 40 years in the trade. Need to be 85% skills, how to use machines . . . no sitting down or writing - it's all manual work.

Teachers have a range of perceptions of technology education and these have been influenced by their interests, experiences in teaching and outside, courses they have attended, their attitude to change and the stage they have reached in their teaching career.

DISCUSSION

Subject subcultures were found to be consistent and were a strong influence on secondary school teachers' perceptions of technology education. Science teachers emphasised applications, social studies teachers focused on societal aspects, English teachers on journalism, media studies and drama, Accounting and Economics teachers mentioned computing and resources, and technical teachers focused on skills, designing and making. While each of these subject areas contributes to technology education, no one teacher had a broad view of technology education.

In the primary schools the subject subcultures did not appear to be as strong, although they did emerge in some of the teachers' comments. There was an emphasis in the school on problem solving and many of the teachers talked about technology education as using technology, particularly computers, to solve these problems. Those teachers with a special interest in science emphasised science and technology. Science specialists saw technology as a vehicle to teach science or applications of science and this view was written in the school schemes. Teachers mentioned making students comfortable with and aware of technology. In the intermediate school technical teachers felt threatened that other teachers in the school would become qualified in their area. They felt what they were already doing was technology. It became apparent that because teachers had a narrow view of technology education they may not be aware of the technology that is already part of their teaching programmes.

Teachers' perceptions of technology education were influenced by their past experiences both in and out of school. Interests in music, computing, all contributed to teachers' views of what technology education might be. Teachers who were beginning their teaching career were concentrating on 'survival' and coming to terms with what they had to teach and technology was seen as an extra. Those teachers who had worked outside of teaching were influenced by these past careers and tended to focus on 'hi-tech' as being the highly visible technology. Where the technology was seen in terms of construction, the focus of the teacher was on manual skills. Those teachers who had been involved in some form of long term teacher development program felt confident about the introduction of technology education, although this was often in terms of science and technology. Interactive teaching had a big influence on teachers' confidence to tackle new subject areas such as technology.

In terms of teachers' views of the management of technology in schools there are different issues depending on the level of schooling. For example at the secondary school level there are problems in terms of developing a cross-curricular approach which teachers at the junior school level appeared to favour. At the intermediate school level, teachers teach a range of subjects, but problems arose in terms of trying to work in with the technical areas.

It was apparent from the interviews with teachers that there is a range of views about technology education and these views will influence curriculum development and implementation in the area of technology. An imposed curriculum that does not take account of the existing ideas of teachers, and the realities of the school could be distorted in such a way as to threaten the improved learning that could take place.

No teacher had a broad view of technology which emphasised the three possible main themes of technology education, that is, technological knowledge and understanding,

understanding and awareness of the interrelationship between technology and society and technological capability (Jones, 1992). Although aspects of each of these were mentioned by individual teachers

This initial research suggests that to avoid the pitfalls encountered by many countries in the implementation of a technology curriculum, account must be taken of the subjective realities of the teachers. Curriculum and teacher development need to grow from these existing conditions.

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REFERENCES

Claxton, G. & Carr, M D. (1991) Understanding change: the personal perspective. SAME papers 1991 p 1-14. Centre for Science and Mathematics Education Research, University of Waikato, Hamilton: Longman Paul.

Fullan, M. (1982) The meaning of educational change. New York: Teachers' College Press.

Goodson, I F. (1985) Subjects for study. In I.F. Goodson (ed) Social histories of the secondary curriculum. Lewes: Falmer Press

Goodson, I F. (1991) Teachers' lives and educational research. In I.F. Goodson & R. Walker (eds) Episodes in educational research. Lewes, Falmer Press

Jones, A. (1992) Goals of Technology Education. Paper presented to the Technology Education Consultative meeting. Wellington.

Lindblad, S. (1990) From technology to craft: on teachers' experimental adoption of technology as a new subject in the Swedish primary school. Journal of Curriculum Studies, 22 (2), 165-175.

Ministry of Education (1991) Draft national curriculum statement. Wellington: Learning Media.

Paechter, C. (1991). Subcultural retreat: negotiating the Design and Technology Curriculum. Paper presented to the British Educational Research Association Annual Conference 1991.

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IMPROVING A PLAYCENTRE SCIENCE PROGRAMME THROUGH ACTION RESEARCH

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ABSTRACT

Attitudes to science develop early in life. In early childhood, the almost exclusively female staff members lack confidence in the area of science, and are therefore unable to develop an adequate science program for their children. In an action research project involving one third of the adults staffing a playcentre, during one term, the science programme in the centre was considerably improved, on measures of dialogues with the children, and of planning activities specifically for science. The staff members, mothers in the playcentre, reported increased confidence in talking with children about science topics, and a significant change in their interaction patterns both with their own families and with other children in the playcentre science programme. The action research method was found to be particularly helpful in supporting the group of parents in improving their centre's science program.

INTRODUCTION

While the majority of personnel working in early childhood are female, and while females continue to be a minority amongst those who consider themselves to be scientifically literate, early childhood centres are unlikely to include adequate science programmes in their curriculum planning. If the adults working with children in the early years can learn to enjoy science, there is the potential for making gains in this area for two generations concurrently. These gains will be for the adults and the children they work with, including their own, who they will continue to influence throughout their schooling as whole families have new interests opened to them. Women and girls, in particular, may have new opportunities made available to them.

I have found that in workshop situations women very quickly realise that they do know and utilise much science in their daily lives, and that it is important for their children that they explicitly plan science experiences in their programs. This project is an attempt to clarify whether, in fact, changes are made in an early childhood science program as the result of the staff members' engagement in action research with a focus on science.

Throughout this study, the emphasis has been on empowering women to conduct their own investigations concerning their current science programs with their children.

Science is an important curriculum area in early childhood because of its potential in helping children use logical reasoning to make links between their observations and their ideas, and in encouraging the use and exploration of language and other cognitive abilities. Skills, knowledge and attitudes developed in the science program can pervade all areas of living and learning. Children who miss out on those experiences in particular areas of the early childhood curriculum which are likely to promote skills and thinking in science, may well already have their pathways to future interests and career choices limited (Meade, 1985).

ACTION RESEARCH

Action research is cyclic: it assumes that educational plans are likely to be modified even before they are put into practice, and that each airing of the plan will lead to further changes. The stages of the cycle are familiar in teacher education: a plan is formulated; it is acted on and at the same time results observed; and after careful reflection, a revised plan is formulated.

The action research group consisted of fourteen adults from one play-centre, comprising about one third of that centre's families, and two from a neighbouring centre. In the first phase of the research, current practice and knowledge in science were identified within the group, with a view to considering desirable and achievable improvements. Discussion identified participants' current understanding of science, and what they required to be able to offer the program they wanted for their children. After this, they decided that their aims were to develop their confidence in science topics, and to improve the resources needed to support their science program. The group planned to meet for two hours at weekly intervals, for six weeks. They agreed to concentrate on learning about a few specific science topics in order to learn the skills of researching the topics of interest which arise with children, and to enhance their confidence.

Action research aims to empower an educational community to manage its own understanding and improvement of its educational practices. With an "outsider" facilitating this process, it is important that any agenda the facilitator may have is shared with the group. The author informed the group that she was interested in working towards developing their awareness of their current science knowledge, their skills in listening to the children and their use of interactive learning to extend children's own ideas. These aims complemented those of the group.

CONTENT OF GROUP MEETINGS

Included in the six evening meetings were:

- discussions on "what is science", "where does it occur in your sessions?", "what do you need to know and do to develop your science program further?" and "what is interactive learning?".
- definition of a dialogue; practice in listening to others, adults and children, and challenging and extending their ideas.
- sessions in which pairs of participants researched and conducted workshops on specific science topics (light/ colour, water, heat, magnetism and batteries/ bulbs) for the whole group, as a method of both learning and reinforcing science content, and practising sharing with others; an important aspect of each workshop was the reporting of children's responses to the equipment and ideas introduced to them. These responses were often video recorded, and the video clips became a feature of the evenings, when the participants agreed to share them with each other.
- critical reviews of their own and others' interactions with the children, using video recordings of recent interactions with children at Playcentre, and considering "what else might we have done/said to further encourage dialogues and ideas?"
- a goal-setting exercise, consisting of developing short- and long-term goals, both individual and for the centre.

This sequence completed the first cycle of planning, acting, observing and reflecting. The reflection stage also produced the revised plan, which consisted of:

* setting a date for presenting their workshops to colleagues who did not attend the course;
* each partnership presenting a workshop, preparing kits of the equipment and guidelines for developing interactive experiences for the children;
* writing articles on the use of the science experiences with children, for the centre's regular newsletter;
* continually updating the science kits, and conducting workshops for groups of new parents.

Measurement of changes made as the result of the project

Records were made prior to the project, mid-way through it, and on completion, of:

* participants' perception of what science is (pre- and post-course only).
* the amount of specific planning in science for Playcentre sessions which the group undertook (a measure of their provision of a science program, and of their confidence in science);
* the number of children with whom the adults were sharing in-depth dialogues during sessions;
* changes in individuals' verbal interactions with children.

The first two measures were ascertained through a centre document search of the records kept for every session by the adults on duty. The third measure, of the number of in-depth dialogues shared with children during Playcentre sessions, was gauged from a questionnaire completed by participants on the first and last evenings of the course. Individual participant interactions with children were recorded on video throughout the project and one adult's records are transcribed in this report.

RESULTS

The researcher expected that, if the project were successful, this would be reflected in a variety of aspects of program planning and in the interaction between the adults and the children. While the adults in the centre worked on developing their confidence in sharing science topics with children, through increasing their science knowledge base, developing resources, and increasing number and depth of dialogues, other important changes were also likely to occur in the Playcentre.

Documented records were searched and further records made in order to ascertain any changes in the group's perception of science, in the number of in-depth dialogues children engaged in during playcentre sessions, in the amount of program planning specifically for science topics, and in individual verbal interactions with children.

Changes in the group's perception of science

Participant response to the question "what is science?" at the first meeting, indicated that science was considered largely as content knowledge. Examples quoted were either specific science topics, such as "earth, power; biology; how things work; the world around us", or activities and equipment, such as "water; sand - textures, light, heavy, wet, dry;

puzzles". Only one respondent mentioned any aspect of science as a process, identifying "the senses".

By the end of the project, participants realised that content and knowledge are no more important than the process and context of science. Responses to the same question as on the first night "what is science?" included the same topics as previously: "batteries; colour and light; sound", and the activity areas, such as "water; cooking; collage; sand; block, and outdoors". The major addition to these lists, which indicate the group's shift in perspective, were the items such as: "science is fun; helping children and adults to ask and answer questions; science is everyday experiences: looking, feeling, smelling, and tasting; thinking about what happens; working together on the 'what happens if... questions'; discovering the world around us, all those things which we come into contact with all the time, and take for granted". Of particular note were the comments related to the context of science for each child, such as "science is motivating the child to go on from here; noticing the world around us from the individual child's point of view".

Record of changes in the Playcentre sessions

A document search was made of the regular session records of program planning and evaluation, which every supervising group at the playcentre records, at the completion of each session.
These records include:

- the number of children assessed by the adults on duty as having shared in-depth dialogues during each session;
- specific planning prior to each session, for activities or outcomes, in the same time periods as above.

A dialogue is defined for the purposes of this project as a sustained conversation of three or more exchanges, with the minimal structure of A-B, B-A, A-B, where the topic of conversation is similar throughout, and each contribution expands on the previous one (Sylva et al., 1980). The number of children with whom adults had held dialogues were tallied for a week at three different times (pre-, mid- and post- project). Both the number of children involved in dialogues and the planning for their topics of conversation, showed significant changes over the period of observation and record-keeping (see Table 1).

Changes in individuals' interactions with children

As the group proceeded through the action research cycle, individual participants also followed the stages, each at her own pace. The following samples of one member's dialogue with children, at different stages in her learning cycle, indicate the changes made in participants' verbal interactions with children.

TABLE 1
DIALOGUES WITH CHILDREN AND PLANNING FOR SCIENCE: GROUP CHANGES ACROSS THREE PERIODS

	Period 1: (Pre - project)	Period 2: (Mid - project)	Period 3: (Post - project)
Number children sharing adult-child dialogues (N = 20)	65 (average 13/session)	78 (average 16/session)	87 (average 17/session)
Specific planning for the week (on a daily basis)	socialisation balancing large muscle	magnets candles batteries compost	large muscle socialisation rotten log chemistry thistle compost light/colour

Dialogues 1: Pre-project period
Scene: An adult and six children outside at Playcentre, investigating trees and logs.

A: Have you seen the buds on this tree?
C1: There's a big hole
C2: Look at the top of it. It's really big.
C3: I can't climb up there.
A: I wonder what was there at one stage? (responding to the "hole")
C2: It's very round
C3: It's where a branch was chopped off. (children with hands exploring the inside of the hole)
A: What does it feel like in there?

This dialogue continued for some 35 minutes, with the adult consistently responding to the children's interests, challenging their ideas, and assisting them to link their past and present experiences.

What more could be expected, in an interactive science program in an early childhood centre? Some possibilities are:

- to be aware of the value of her dialogues with the children, and of the science she was experiencing with them;
- to plan to follow-up specific interests of the children, as often as possible, so that projects become ongoing; children need experiences which confirm that their ideas are valid, and that they can themselves plan their activities.
- encouraging the children to do more of the talking and the thinking than the adult.

This adult was not aware that she was engaged in a science program! As a relatively new mother at Playcentre, she indicated that she was unsure of both how to talk to children and how to extend their interests and activities. After viewing and discussing the video recording of the above dialogue, and participating in the project group's decisions concerning plans for improving the centre's science program, this mother set out to improve her own science interactions with children. Her science workshop topic was magnets, a new area for her.

Dialogue 2: Mid-project period
Scene: The same adult preparing for her workshop on magnets, through sharing her ideas and resources with the children.

A: What's happening?
C: It's moving
A: What's making it?
C: The magnet
A: If it works through paper, do you think it will work through...this? (glass)...this? (baking tray)...this? (wood). (Adult tries each sheet)
C: I want to try this sand
A: There's sand in this box. Put the magnet underneath. What's happening, Dominic?
C: They're moving
A: OK. That's iron sand. This is ordinary sand out of the sand-pit. Will it work with this?
C: No.
A: Why does it work with this and not this?
C: Cause it's wet.
A: Yes, it's wet. Let's try with dry sand and with wet sand. (Adult made the sand wet). Now try the magnet. Does it work with wet sand?
C: No.
A: OK. I'll show you something (sets up paper-clips in a cup, with the magnet on the outside to slide them up to the top).
C: (shows little interest, and wanders away)

The child was initially very interested in the equipment, and wanted to experiment. However, the adult had her own, more pressing agenda; she, in effect, became quite didactic, doing all the thinking and setting up herself, with the result that the child wandered off.

The adult was reasonably aware of the reasons for what she called her "disastrous magnet session!" After she viewed and evaluated the video clip, she developed her "revised plan", which consisted of consciously practising the following:

- listening to the child's interests;
- keeping my new knowledge to myself, until it is relevant to the children to share it with them;
- becoming more aware of the books/puzzles/equipment available with which to follow-up children's spontaneous interests.

Because this adult agreed to share this video clip with the group, many others had the opportunity to be forewarned about the temptation to adopt the "transmission approach" to sharing information with children, at the expense of "interactive learning" (Biddulph & Osborne, 1980). The same adult agreed to being videoed interacting with children for the third time, while attempting to achieve the aims identified in her "revised plan".

Dialogues 3: Post-project period

Scene: The adult, with two children doing puzzles, on the floor during a Playcentre session. The current puzzle depicts various water animals.

A: Tell me about all these animals.
C1: They are all living in the water. Look, here's a sea horse.
A: Wow! Have you seen a sea-horse?
C1: Yes.
C2: I have too.
A: Tell me about where you saw these sea-horses?
C1: We found a lot of sea-horses. And mmm mmm mm, jelly- fishes. Some good ones and some squashed ones.
A: Were they alive?
C1: Yes, the good ones were. And we had to be careful so they didn't sting us. So we just played on the beach, and kept away from the squashed ones.
A: That was a good idea.
C2: Yes, because they might sting you if you go in the water. But sometimes they don't, because we want to swim there. Why do they want to sting us?
A: I don't know why they sting people. Perhaps we just get in their way. I think we've got a book about jelly-fish and sea-horses. Shall we go and find it, and see if we can find out more about them?

On reflecting on this short dialogue, the adult discussed the books available for extending and challenging the ideas on sea-horses and jelly-fish. She was well aware that she and the children were engaged in interactive learning in science, and that she did not know much about the topic which had arisen. She also knew that books were available in the centre, and that she and the children could together investigate, with the children taking the lead!

Note that these children talked more than the adult did, and that the topic remained in their control at all times. This adult seems to have reverted to her interactive learning style with the children, with the addition of her now clear understanding of her own role in extending the dialogues and the thinking in science of the children.

DISCUSSION

Action research, specifically utilising Kemmis and McTaggart's action research planner (1988) facilitated the work this group of Playcentre parents accomplished in developing their science program. Action research is about collaboration in program improvement and about communities of educators becoming more reflective. This project indicated the value of groups of early childhood educators meeting and forming networks, to encourage their continued reflection on their own programs.

The most useful aspects of the Kemmis and McTaggart's action research planner (1988) were found to be:

- their holistic approach to research, in which every aspect of the educational institution is understood to contribute to what happens in it;
- the insistence that the research belongs to the community being researched. As the title implies, the purpose of action research is to link the action with the research, in trying out new ideas in practice as a means of improving education, and as a way of increasing knowledge about curriculum, teaching and learning. In conducting their own research, teachers, parents, and administrators have the opportunity to both improve and to gain a better understanding of what they do.

In working through the action research cycles, this group of early childhood educators was able to identify the specific areas of their science program requiring development, and how they might proceed. They modified their plans in the light of successive reflections: they instituted significant changes in the amount and quality of verbal interaction, on topics of science, with the children in their program; their planning for science increased; and their confidence in themselves as scientists and their understanding of science increased. Almost incidentally, the interactive learning style which these women adopted was reinforced. Their program has been enriched, not only with the resources developed by the participants but of greater importance, with increased understanding in these women of their role in developing their children's attitudes towards and skills in science.

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REFERENCES

Biddulph, F., & Osborne, R. (eds.) (1980). Making sense of our world: an interactive teaching approach. Science Education Research Unit, University of Waikato, Hamilton, New Zealand

Kemmis, S., & McTaggart, R. (1988). The action research planner. (3rd edn) Geelong: Deakin University

Meade, A. (1985). The children can choose. Wellington, New Zealand: NZCER

Sylva, K., Roy, C., & Painter, M. (1980) Child watching at playgroup and nursery school. London: Grant McIntyre

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RETRAINING CHEMISTRY TEACHERS IN THE PHILIPPINES

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ABSTRACT

A recent large scale educational aid program to the Philippines included the retraining of secondary chemistry teachers. Teachers were introduced to new content and to alternative teaching strategies. An initial resistance to change arose as it was perceived that the new approaches did not take into account very limited school facilities and very large teaching groups. The lecturing style of teaching, which predominates at all levels throughout the country, was seen as the most effective method to handle overwhelming classroom problems. Resistance was overcome after alternative teaching styles were modelled. This paper gives an overview of the aid program and outlines the introduced teaching strategies. It contends that Asian teachers have been largely unaffected by western educational aid due in part to the fact that such aid is rarely accompanied by the modelling of introduced strategies.

INTRODUCTION

In the mid-1980s the Philippines instituted a reform program in the primary and secondary sectors of education. The program focuses on curriculum reform, production of instructional materials, provision of equipment and staff development. This was part of a long term aim to raise national productivity and establish economic stability. For details, see UNESCO (1991).

The Australian Government is assisting in this reform through PASMEP: Philippines-Australia Science and Mathematics Education Project. The prime objective is to improve secondary science and mathematics education. The teaching of these subjects had been identified as being particularly in need of reform due to a lack of textbooks, teaching aids and materials; a shortage of trained science and mathematics teachers; and, ill-equipped science laboratories. "Science and Technology" is the official term under which science studies are undertaken in the Philippines. Science and Technology I and II (Grades 7 and 8) cover general science and biology. Science and Technology III and IV cover chemistry (Grade 9) and physics (Grade 10).

Science had been taught in Philippines' secondary schools, with little or no experimentation or practical work, a situation often attributed to very large class sizes and lack of space. This situation was compounded by a sharp increase in enrolments resulting from the introduction of free secondary education in all public schools. School populations were often so large that children had 'wait time' between classes as there was insufficient teaching space to accommodate all enrolled children in class at the one time. Noise was a natural consequence of leaving children on their own. To cope, teachers wrote blackboard notes which children copied. Such difficulties meant that a survival teaching mode of lecturing was almost universally accepted in schools. It is also fair to say that the Australian based lecturer-advisers had little prior knowledge or experience of these conditions. Ninety percent of science and mathematics teachers are women, (Jones & Boyle, 1991) and only 16% of chemistry teachers are qualified to teach chemistry (Australian Embassy, 1990). It is within this context that PASMEP was initiated.

PASMEP

The project provided for specialist training in Australia and in the Philippines for 230 selected Filipino teachers and teacher educators. Within Australia some 30 Filipino teachers had studied chemistry at the University of Tasmania, 30 had studied physics at

Monash and 60 had studied mathematics at Edith Cowan University. Teacher educators, with expertise in these fields, had also studied in Australia. There were approximately 60 in this latter group. This paper deals with aspects of the chemistry element of the project. Two chemistry teachers were selected from each of the 14 administrative regions in the Philippines. In addition, one teacher came from the Bureau of Secondary Education (BSE) and one from the University of the Philippines making a total of 30 in all. Upon returning to the Philippines they were paired with two additional chemistry teachers from each region. Each of the 14 regions thus had four teachers (56 in total for the entire country) who were required to teach all the other chemistry teachers through a process called mass training. This process was already in use as part of the overall reform of Philippines primary and secondary education.

THE AUSTRALIAN CHEMISTRY PROGRAM

The teachers were engaged in a 10 month program conducted jointly by the Department of Chemistry and the Faculty of Education at the University of Tasmania. The program consisted of: an upgrading of chemistry content knowledge and laboratory techniques; chemistry education and teaching; planning and evaluation of training programs in chemistry education; leadership and the management of innovation; and school, college and chemically based industry experience. The enhancement of teaching skills was a key element in this program and modelling was foremost among the various strategies employed. Modelling has long been recognised as an effective behaviour modifier and its use in teacher education programs has been variously reported (Turney, Clift, Dunkin & Traill, 1973; Joyce & Weil, 1986; Tisher & Klinzing, 1992). Specifically, in science education Tobin, Pike and Lacey (1984) reported positive results when using modelling techniques to improve the quality of trainees' activity-oriented science teaching skills.

MASS TRAINING

Within each administrative region selected schools became the Regional Leader School (RLS) for a particular subject of the curriculum. When mass training was to occur for that subject the RLS would host all the teachers in the region. They would attend classes, eat, sleep and generally live in the school for the two weeks of training. For chemistry mass training, the number of teachers involved averaged about 180 per RLS which meant that class sizes averaged forty five. In most regions the program was repeated after a week's rest for the trainers. In regions which opted to have only one session, class sizes increased up to 80. Some 4,000 teachers of chemistry were retrained in this way.

Preparation for Mass Training

Soon after the group returned from Australia to the Philippines final preparations for mass training commenced and included two workshops. At the first, the trainers were introduced to the new science and technology text book for Grade 9 by the local educators responsible for its preparation. Lecturer-advisers from the University of Tasmania attended as observers. It was at this stage that a major problem emerged.

The Australian advisers, including the Australian PASMEP coordinators based in Manila, had quite clear ideas on the style of teaching which might facilitate desirable reform of science teaching. In short, it was believed that approaches which involved student participation and interaction would be essential to the reform process. Filipino advisers, on the other hand, indicated that the only practical way to handle a mass training situation was to use lecture style approaches. At this crisis point, Australian advisers reasoned that no change would occur unless trainers modelled new approaches. A complicating factor was the issue of equipment. As part of PASMEP, Australia was providing kits of mathematics, chemistry and physics equipment to all RLSs, to each school that had a trainer on staff and to every secondary school in Regions 2, 7 and 10. (Some 375 science-mathematics laboratory kits were to be distributed.) It was feared that the science equipment would not be used unless mass training involved practical activities using the science equipment. The fact that science teachers in the Philippines were required to bear the cost of equipment breakages was another complicating factor which reinforced the lecture approach in science teaching. It was feared that this situation would continue unless alternative strategies were modelled.

TEACHING STRATEGIES

In an endeavour to rectify the problem of utilising new teaching strategies, an additional two-week workshop was organised at which selected teaching approaches were introduced and practised by the trainers. Visits to local schools helped advisers select five strategies for presentation. These were modelled and the trainers adapted them to the content in the new chemistry textbook. The five strategies were:

> Role Play: Students act out aspects of science or science history. It was the most popular of all strategies.
>
> Predict-Observe-Explain: (commonly called P.O.E. but renamed in the Philippines as PROBEX). In this method the teacher demonstrates a phenomenon and then changes the conditions slightly. Students are asked to predict what will happen. The teacher manages the predictions in such a way as to encourage thinking and sharing of ideas. Predictions are made public and further discussion may take place. Predictions may be changed or reinforced by the discussion. The students now observe the experiment under the changed conditions. Observations are matched with predictions and explanations given. This method was the second most popular strategy among the trainers.
>
> Mixed-up Recipe: In this strategy students apply knowledge. For example, the teacher puts up a "tangled recipe" for the preparation of a compound. Students

are required to sort the steps using previous knowledge/experience. This was also a popular strategy.

Concept Mapping: This is a strategy which can be used to introduce new work, revise work or help in remediation. A number of concepts are displayed and the students attempt to link these with connecting phrases which explain the nature of the link. Popular, but most often used as a summary or as an assessment technique.

"Yes" - "No" Enquiry: A teacher confronts students with a new or puzzling situation. The students seek an explanation from the teacher by asking questions to which the teacher can only reply "yes" or "no". From the responses the students build an explanation. This was the least popular of all strategies.

(For an elaboration of these strategies see Grant, Johnson & Sanders, 1990)

Trainers demonstrated the strategies to principals of all RLSs (chemistry) who attended the later stages of the workshop along with senior science staff and regional science supervisors. This workshop was a very positive event which became a turning point after which much of the previous tension between the partners in the project evaporated.

FINAL PREPARATIONS

At the time of the final preparatory workshop some 6 weeks later it was presumed by advisers that fine tuning was all that remained to be done. During the practice sessions it became obvious that in the period between the workshops a reversion to 'lecturing' had occurred. The trainers appeared to have had second thoughts and also conveyed that we, the Australians, did not realise what mass training was like! Teachers were obliged to attend mass training during the intensely hot summer vacation period. There was no payment for attendance yet failure to attend resulted in discipline and loss of privileges, such as leave entitlements. Teachers, mostly female, had to leave families for two weeks. Previous mass trainings had been negative experiences where trainers were openly criticised. Chemistry trainers could now expect such criticism. Further, all trainers were assessed by visiting BSE personnel and professional advancement was certainly influenced by this assessment. Thus, the chemistry trainers reasoned, it was best to revert to lecturing. Lecturing was expected and accepted. A severe loss of confidence infected the group as they reasoned that the strategies they had practised, and the teaching approaches seen in Australia, would not work under Philippines conditions.

To restore confidence and demonstrate that interactive teaching could be successful a PROBEX based lesson was modelled by Australian advisers in conditions that approached those which would be found at mass training. Such a full scale rehearsal had not been attempted previously as it had not been thought necessary to do so. The lesson was well received and the challenge given for a trainer to show that she could also handle a group in a simulated mass training situation. It must be pointed out here that each trainer had been selected as an outstanding teacher in her region and had mastered, to varying degrees and in small group settings, the techniques required to implement the teaching strategies introduced during the second workshop. Nevertheless, most remained unconvinced that these ideas would work in schools, given all the problems facing science teachers in the Philippines. However, the success of the modelling can be measured by the fact that one trainer volunteered to teach the whole group the next day. She used a combination of the strategies and was highly successful, finishing to applause. This was, undoubtedly, a second turning point from which preparation proceeded with enthusiasm.

THE CHEMISTRY MASS TRAINING

Chemistry Mass Training occurred during the months of April and May, 1991. An important element was the role of RLS principals who had seen the new strategies demonstrated at the second workshop. During ceremonies to officially open the Chemistry Mass Training it was reported that principals across the country had indicated to the trainees that this mass training would be different. They would see new ideas and equipment which they would be able to use in their own schools and classrooms. The trainers, in the great majority of cases, were able to capitalise upon this positive beginning and lived up to the raised expectations. Australian advisers visited RLSs in 9 of the 14 administrative regions, access to the others being restricted due to social unrest. These visits enabled assessments to be made but also, as it eventuated, provided a morale boost for some very nervous chemistry trainers. All associated with the mass training agreed it was very successful (White, 1991).

Mass Training Teaching Tasks

There were three prime presentation tasks for each teaching session: the introduction of new content material from the text book; the demonstration of equipment usage; the modelling of teaching strategies deemed appropriate for the content. The sessions usually ranged in length from 75 to 90 minutes. During the last 15 minutes of each session trainers were encouraged to help teachers recall the lesson steps; how interaction was encouraged in the group, how people were managed, how thinking was encouraged and so on. Such an approach had never been used in previous mass trainings and it was this element that received much favourable comment. In a number of cases principals of the RLSs initiated a competition among trainees to see who could best emulate the demonstrated strategies. These teaching sessions were held after hours and proved very popular.

Problems

Trainers usually commenced work at 8.00 am and worked with class groups usually 45 and above. Some classes reached sixty, and at one RLS exceeded 75. Classes were often held at night and for six days of the week leading to exhaustion as a natural consequence. Trainees' chemistry knowledge varied widely and pre-test results confirmed that many would require extra tutoring. Trainers were also responsible for the demonstration of the new PASMEP equipment. However, despite the widespread distribution of the science kits the fact remained that the majority of secondary schools would not receive new equipment. Thus, trainers were also required to suggest and demonstrate equipment alternatives, so adding an additional burden.

DISCUSSION

Despite an apparent acceptance of the science teaching approaches observed by the trainers while in Tasmanian schools and colleges, it seems that the influence of this modelling was not sufficient to change their practice in the Philippines. One reason for rejection appears to relate to the context in which the strategies were modelled. PASMEP chemistry trainers were unable to relate modelled Australian science teaching with conditions in the Philippines.

Although no formal evaluation of the chemistry retraining program conducted in Australia has as yet been undertaken, in hindsight it seems clear that the failure to analyse the component parts of observed lessons was an oversight. Thus for example, a teacher model using predict-observe-explain in the introduction of a lesson, would also use many other teaching skills throughout the rest of the lesson. Holistic lesson modelling demanded too much of the trainers, presumably because of both context problems and a lack of knowledge of what to look for. The result was that lesson elements which enhanced student activity and verbal interaction were apparently "lost" in the total observation.

Although this paper has only dealt with PASMEP Chemistry it is possible to generalise about aspects of educational aid in developing countries. While the PASMEP approach breaks new ground, Asian countries, including the Philippines, use formal examinations as a means of selecting students for advancement. These examinations often commence at kindergarten level. The examination pressures upon schools, teachers, children and parents are overwhelming. Even PASMEP's innovative influence must be doubted if the examination system in the Philippines continues to exert the influence it currently has.

The number of Asian scholars trained in the west is vast, yet the influence of western education systems on Asia is muted. Teachers there do not usually plan to actively involve students in lessons. Interaction, co-operation and problem solving methods which can encourage thinking are seldom used in Asian schools. There are certainly constraints to using student-centred approaches in Asian classrooms and a number of these have been mentioned. However, whilst acknowledging the constraining factors, the chemistry experience in PASMEP brings to light another inhibiting factor which is more subtle than problems of overcrowding or lack of equipment. While many Asian academics study in western countries their work is usually at the tertiary level where they are unlikely to see modelling of teaching methods such as those outlined in this paper. Even if they do see modelling of alternative strategies, the context is not familiar. When PASMEP chemistry trainers in Tasmania observed expert science teachers at work, their observations apparently became mired in questions of transferability and appropriateness for Philippine conditions.

The use of a variety of teaching strategies enhances understanding and assists content gain. They are used to enhance learning by introducing variety, by tapping into the different ways in which people learn and by generally increasing enjoyment in learning. These points were appreciated in the Philippines. But even though these Asian teachers may have read or heard of alternative teaching strategies in their education studies during teacher preparation courses, modelling was rarely used to illustrate the approach in the local context. The strategies generally represent nothing more than a theoretical consideration covered in a course.

CONCLUSION

The A$18 million project is drawing to a close. The starting point was a policy initiative by the Government of the Philippines to undertake educational redevelopment. The direction and "ownership" of the redevelopment remains with the Philippines but is aided by Australia through PASMEP whose functions and aims are wide ranging and go beyond the direct training of teachers. Curriculum development and the institutionalisation of in-service training of teachers are also part of its brief. This will be achieved by the establishment of a network of training centres in different parts of the country. The project has also influenced educational administrators and involved teacher educators in its programs. At the classroom level it has introduced teaching methods which are student-centred and more process-oriented. It is estimated that through all its programs PASMEP will benefit 200,000 Filipino students a year (Jones & Boyle, 1991).

The PASMEP experience illustrates that it is possible to bring about quite radical changes in classroom practice in Asian schools despite the many difficulties teachers face. To do this, the focus of educational aid must include role modelling in an appropriate setting. Apart from this one example, observations of teaching practice throughout Asia has led me to the conclusion that most people at the chalkboards there have largely been unaffected by western educational aid.

REFERENCES

Australian Embassy, Manila, (7 Dec. 1990). Press Release No. 012 Innovative approaches to science and math education, 1-3.

Grant, P., Johnson, L. & Sanders, Y. (1990). Better links: teaching strategies in the science classroom. Parkville: STAV Publishing.

Jones, D. & Boyle, B. (1991). $18m project enhances Philippine education and Australian industry. Focus 5 (1), 19-25.

Joyce, B.B. & Weil, B. (1986). Models of teaching (3rd edn). Englewood Cliffs NJ: Prentice Hall.

Tisher, R.P. & Klinzing, H.G. (1992). Procedures to developing classroom teaching skills: modelling, cases, simulations and micro-teaching. South Pacific Journal of Teacher Education, 20, 35-48.

Tobin, K., Pike, G. & Lacey, T. (1984). Strategy analysis procedures for improving the quality of activity-oriented science teaching. European Journal of Science Education, 6, 78-89.

Turney, C., Clift, J.C., Dunkin, M.J. & Traill, R.D. (1973). Microteaching: research, theory and practice. Sydney: Sydney University Press.

UNESCO/APEID Regional Workshop on Science and Technology (1991). Science for All and the Quality of Life. Bangkok: UNESCO.

White, G. (1991). Report: Field evaluation of mass training 1991. Manila: PASMEP.

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SCIENCE AND TECHNOLOGY MANAGEMENT: DESIGNING AN UNDERGRADUATE COURSE

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ABSTRACT

This research focusses on the role of science educators in preparing technically educated graduates for their careers. A comparison was made between the skills and abilities in science and technology students desired by industrial employers and whether New Zealand graduates exhibit these qualities. To address some of the management-based issues identified by the research, the design of a new Science and Technology Management course is outlined.

INTRODUCTION

The growing role of science and technology in modern New Zealand society has created a need for unique management skills on the part of scientists and technologists. Not only is science and technology a fundamental part of the modern New Zealand way of life, it is now recognised as being an essential ingredient of economic growth and progress (Bollard, 1986; Beattie, 1987). Improved science and technology leadership is being increasingly recognised as an imperative in our times.

Scientists and technologists generally have a sound knowledge of their own subject area and a grasp of various technologies which impinge upon their expertise in the organisations they work for. These professionals have the potential to produce a great number of important discoveries, innovations and inventions. But do enough science and technology graduates have some understanding of the day-to-day principles of management? Is there sufficient awareness of business strategy and marketing techniques? Is there a failure of communication between business and science? Various studies show that these two groups do not interact well, largely because of communication difficulties and insensitivity to each other's capabilities and perspectives (Gupta, Raj & Wilemon, 1986, 1987; Weinrauch & Anderson, 1982). Other barriers to integration of management and science/technology include educational backgrounds (Badawy, 1982) and personality and cultural differences that are emphasized by sterotyped perceptions of "managers" and "scientists" (Gupta et al., 1985).

One purpose of any science education programme is to place graduates in a position from which they can embark upon further learning competently and confidently. A useful way of evaluating this, is by considering the goodness-of-fit between what science graduates take into the world of work and the requirements for rapid learning on the job. Despite its importance, little science education research has been conducted into the learning that takes place during a career and how this might be facilitated by the features of initial (undergraduate) science education programmes (Powell & Banks, 1989). An initial study into developing professional skills in chemistry students had indicated a considerable mismatch between the skills and qualities New Zealand employers desire in recent graduates and those they find (Kirk, 1988). Questions were raised about the need for a more formal integration of business and management skills into traditional Chemistry undergraduate programmes and the need for integrated curriculum material to enhance the development of these wider skills. A second phase of how to develop "desired professional qualities" across a broader range of science graduates is reported here.

THE PRESENT RESEARCH

Given the above, this research was guided by two questions: What qualities and skills in scientifically educated undergraduates are desired by industrial employers? Are science/technology educators currently helping to meet the needs of these employers? The aim was to identify information to help educators in science/technology, in the preparation (and development) of graduates so as to better provide for the science and technology needs of New Zealand.

Data Collection A pre-tested structured mail questionnaire, based on previous extensive interviews (Kirk, 1988), was sent to the Chief Executive of each of 461 industrial firms and laboratories in New Zealand. In all, 182 completed questionnaires were returned (39%), of which 167 were valid (36%). Sixty percent of these companies (103, 22% of total sample) had hired science and/or technology university graduates over the past five years. This sub-sample of companies forms the basis for analysis.

Reference to the literature and expert opinion determined twenty-four skills and abilities relevant to managers in science and technology (see Table 1). These qualities fell into four broad categories: General Management (eg decision-making skills), Functional Management (eg basic marketing skills), Personal Skills (eg the ability to work in a group), and Science or Technology-based abilities (eg theoretical knowledge of science and/or technology).

TABLE 1
CLASSIFICATION OF SKILLS/ABILITIES AS USED IN THIS RESEARCH

GENERAL MANAGEMENT	FUNCTIONAL MANAGEMENT
Decision-making skills	Financial control skills
Problem-solving skills	Basic accounting skills
Supervisory skills	Basic marketing skills
Project management skills	An understanding of industrial relations
Planning skills	An understanding of legal matters

PERSONAL/INTERPERSONAL	SCIENCE OR TECHNOLOGY-BASED
Ability to learn "on the job"	Theoretical knowledge
Willingness to accept new values	Analytical skills
Written communication skills	Technical research skills
Oral communication skills	Literary research skills
The ability to work independently	Basic technical skills
The ability to work in a group	Practical work experience
	Computer programming skills
	Computer operating skills

Measures
The questionnaires obtained data on the qualities of science or technology university graduates that industrial employers would like to find (i.e. "wanted"). A five point scale was used, ranging from "Very Important" 5 to "Not At All Important" 1. The extent to which these qualities are found in recent university graduates was measured on a similar scale, ranging from "Always Found" 5 to "Not Found At All" 1. Finally, the questionnaire provided respondents with an opportunity to comment on how university graduates in science or technology could be made more valuable to their organisation. The ten largest performance gaps (perceived difference between "wanted" vs "found") were: Written communication; Oral communication; Planning; Problem-solving; Project management; Decision-making; Willingness to accept new values; Ability to learn "on the job"; Ability to work in a group; and Analytical skills. The additional comments sought from employers on how graduates could be made "more valuable" identified the skills and abilities given in rank order in Table 2.

TABLE 2
CLASSIFICATION OF RESPONDENT SUGGESTIONS ON HOW SCIENCE AND TECHNOLOGY GRADUATES COULD BE MADE MORE VALUABLE

	(% of companies responding)
Improved communication skills (oral/presentation skills; report writing)	26%
Exposure to management skills (planning; decision-making; problem-solving; marketing)	25%
Ability to apply theory practically	16%
Improved skills in basic science	13%
Practical work experience	12%
Improved attitudes (understanding reality vs theory; standards of conduct; work expectations)	12%
Lateral thinking (flexibility in approaching problems)	11%

Overall these results strongly indicate that a number of the mismatches between the skills desired and those found by employers of recent science and technology graduates were centred around various management-based skills.

A SCIENCE AND TECHNOLOGY MANAGEMENT COURSE

With the information gained from this and the previous study (Kirk, 1988), the next challenge was how to put these findings into practical effect. The School of Science and Technology at the University of Waikato offers traditional science majors in Biological Sciences, Chemistry, Computer Science, Earth Sciences, Mathematics and Physics. The

School is strong in the traditional science culture with the "technology" designation in its title being relatively recent (1989) and representing fledging programmes with a Technology bias. The School offers a typical 3-year BSc degree and a "co-operative educative" 4-year BSc(Technology) programme. The latter incorporates a total of 12 months of science/technology work experience into the academic programme. In order to offer students the option of choosing a management oriented course specifically designated to help meet the identified needs of the workplace, the School agreed to a proposal that a course be designed for students at second year undergraduate level. The proposed course was seen as being particularly suitable for BSc(Technology) students who were already in a programme that would meet some of the practical "needs" identified in Table 2 (Kirk & Langdon, 1990), but was to be available to all students regardless of major or degree. Within these considerable constraints, a Science and Technology Management course was designed.

In keeping with the research findings, the aims of the course were to present introductory business and management concepts in a science and technology framework and to increase awareness of how management and business skills and knowledge interface with the world of science and technology. The first difficulty to be addressed was that the School of Science and Technology itself had no specific management education expertise within its existing staff. However the University's School of Management Studies had a strong reputation and there was general recognition by both Schools that closer interactions would be desirable. A second difficulty for an educator faced with the desirability of including non-scientific topics in undergraduate courses is the scope and depth of such coverage. After considerable discussion it was decided that this new course was to be organised as a number of short discrete modules, an approach which is often adopted at graduate level (eg MBA programmes), but much is less common with undergraduate papers. After discussion with staff of the School of Management Studies the main topic areas to be included were: New Zealand Science and Technology Businesses; Human Resource Management; Marketing Goods and Services; Total Quality Management; Accounting for Resources; and Communication. Other important business management topics could have been included but of necessity an introduction could be given in relatively few areas. (A follow-on course at third year could possibly deal with additional topics).

This approach had a number of potential difficulties. Firstly, academic staff who normally spent a whole year giving introductory papers in their specialist management areas were asked to "compress" this to about 20% of a one year paper. This meant experts in their field were asked to crystalise material into a form that could be understood by students who had never taken a management course before and which was oriented towards the business of science and technology. Secondly, a consequence of the "series of modules" approach meant that new staff members presented each section. Thus, the course could easily be perceived by students as a chaotic and unconnected "smorgasbord" of information delivered by "outsiders" instead of a well coordinated and integrated introduction into the world of business and management.

In order to minimise this possibility, the course was deliberately promoted as a "Science and Technology Course" and was organised and coordinated by a member of the School of Science and Technology. The Coordinator was present throughout the course, contributed to the introduction and wrap-up sessions, introduced the management staff lecturers and organised guest speakers. The course was first offered in 1991, is unique in New Zealand and attracted 102 enrolments in its inaugural year. Student evaluation at the end of this year was generally favourable (details available from authors on request) and, with minor alterations, the course has been offered again in 1992.

Conclusion

Despite the positive outcomes of this initiative, fundamental questions remain to be considered. For example:

- How beneficial will such a course be to the students in the longer term?
- Is it sufficient to merely raise students' awareness of business and management issues at the undergraduate level?
- Should options be considered that fully integrated larger inputs from business/management and from science/technology?
- Is it appropriate to consider the development of fully integrated science and management undergraduate degree programme?

Many challenges clearly lie ahead for educators at the science-management interface.

REFERENCES

Badawy, M. K. (1982). Developing managerial skills in engineers and scientists. New York: Van Nostrand Reinhold.

Beattie, D. (1987). Key to prosperity: Science and technology. Wellington: Report of the Ministerial Working Party.

Bollard, E. G. (1986). Science and technology in New Zealand: Opportunity for the future. Wellington: National Research Advisory Council

Gupta, A, K., Raj, S.P. & Wilemon, D. (1985). The R & D marketing interface in high technology firms. Journal of Product Innovation Management, 2, 12-24

Gupta, A, K., Raj, S.P. & Wilemon, D. (1986). R & D and marketing managers in high-tech companies: Are they different?". IEEE Transactions on Engineering Management, Vol EM-33, No. 1, 25-32

Gupta, A, K., Raj, S.P. & Wilemon, D. (1987). Managing the R & D —marketing interface. Research Management, (March-April), 38-43.

Kirk, C. M. (1988). Developing professional skills in chemistry: An initial study, Research in Science Education, 18, 1-8

Kirk C. M. & Langdon, A. G. (1990). Co-operative education in chemistry. Chemistry in New Zealand, 54, 125

Powell, J.P. & Banks, P. C. (1989). Learning during a professional career. International Journal of Career Management, 1, 35

Weinrauch, D.J. & Anderson, R. (1982), Conflicts between engineering and marketing units. Industrial Marketing Management, 11, 291-301

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REPORTING TO PARENTS: SCIENCE IN THE CONTEXT OF THE TOTAL PRIMARY CURRICULUM

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ABSTRACT

What is written in reports to parents can provide insight into the perceptions of teachers of the various areas of the primary school curriculum. This paper reports the first stage of a research project focussing on reports as a guide to teachers' views of the relative importance of, and desired student outcomes in, key areas of the curriculum. Teacher comments in the end-of-the-year reports in one primary school were analysed.

INTRODUCTION

Despite all of the energy that has been expended in research and development in the area of primary school science (e.g. Biddulph & Osborne, 1984), and the quality of work done, there still are many young children "being denied access to learning in this important area of human knowledge and endeavour" (Department of Employment, Education and Training, 1989, p. 80).

The present authors intend to conduct research designed in the long term to increase the exposure of children in primary school to quality science education. They have chosen to use an entry point as yet apparently unexplored, that is, through the reporting of pupil progress to parents.

The major research question being addressed is:

> Can the reporting of children's development in primary science and the teaching of science in the primary school be improved by providing an analysis for teachers of their current reporting practice?

The thrust of the study is based on the assumption that reporting is a compulsory and public activity for all primary school teachers and so may be an issue which will capture their attention. In some studies, researchers have used report cards as a guide to the importance that teachers place on various outcomes of classroom activity. Freeman and Hatch (1989) analysed kindergarten report cards from Ohio Public Schools, and found an emphasis on academic skills in work habits and reading and maths readiness. Thus, it may be possible to focus teachers' attention on science through an analysis of reporting practice in ways that will improve the quality of science teaching. Further, science may be a subject about which parents are concerned and hence interested in the reporting.

REPORTING TO PARENTS

The State Board of Education in Victoria has recently endorsed the importance of effective reporting to parents. It proposed that, "Formal written reports to parents will be issued at least twice a year and cover the full scope of student competencies. They should include:

- assessment of levels of achievement of knowledge and skills in all areas of the curriculum
- comments on attitudes and values being developed in all areas of the curriculum." (State Board of Education, 1992, p.12)

Clearly, there is an expectation that teachers will report to parents concerning the development of the child with respect to each of knowledge, skills and attitudes and values, in all areas of the curriculum.

THE RESEARCH QUESTIONS

Two questions have guided this preliminary study:

- Are there differences between science and other subjects of the curriculum in the various areas of development, that is, skills, knowledge and attitudes, reported in primary school end-of-the-year reports?
- Are there differences between grade levels in the recording of development in Science in primary school end-of-the-year reports?

METHOD

For this first stage of the research it was decided to investigate the reporting in one school. The school was not chosen at random but was one with which one of the authors had extensive contact. After appropriate consultation and negotiation of confidentiality, all of the end-of-the-year reports for 1991, except for Grade 6, (name of student and teacher deleted) were photocopied by a school employee. This provided reports on children prepared by class teachers.

After initial inspection of the reports by the authors it was decided to code the comments made by the teachers in the various parts of the curriculum by means of phrases and words which indicated areas in which the students' development was being reported. There was no analysis of the level of achievement or of any linkages between the various areas being reported.

For example, the following extract from a report: "Jacinta is developing her word attack skills. She is hesitant, and slow to work out new words, but her blending skills are developing. Her sight vocabulary is growing with practice", led to the list

- word attack skills
- blending skills
- sight vocabulary.

The elements of the lists so developed were then classified as relating to skills, knowledge or attitudes.

It was decided to focus only on Reading, Written Language, Spoken Language, Mathematics and General Studies. General Studies is a term used in the school to describe work in Science and Social Studies. In each class of the school these subjects were taught, and hence reported on, by the home teacher. The areas of the curriculum in which the data were not used were Art, Library, Music and Physical Education. These subjects were not always the responsibility of the class teacher.

CONCLUSIONS FROM PRELIMINARY DATA ANALYSIS

With respect to the first question it is clear from the data that the reporting in General Studies and hence Science is very different from that in Mathematics and Reading. In Mathematics there is a significant amount of reporting about development in the students' knowledge. By contrast there is practically none, and none related to particular topics, in General Studies.

Further, for Reading more than half of the comments classified as pertaining to skills are comments on 'reading skill' in general, whilst the remainder relate to specific skills such as decoding and blending. By contrast in General Studies there is no comparable broad overarching skill.

The second research question related to differences across the grade levels in the recording in Science. The data show that there are global differences in reporting across the grade levels. In all subjects there were more comments made in the reports of the children in the junior grades than in the upper grades. This difference is more pronounced in General Studies than in Reading, Written Language and Mathematics.

REFERENCES

Biddulph, F. & Osborne, R. (1984). Making sense of our world. Hamilton: Science Education Research Unit.

Department of Employment, Education and Training (1989). Report of the discipline review of teacher education in mathematics and science. Canberra: Australian Government Printing Service.

Freeman, E.B. & Hatch, A.J. (1989). What schools expect young children to know and do: An analysis of kindergarten report cards. Elementary School Journal, 89, 595-605.

State Board of Education (1992). Reporting student progress to parents. Melbourne, Victoria: State Board of Education.

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STUDENTS' UNDERSTANDING OF CONCEPTS RELATED TO EVAPORATION

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ABSTRACT

Collis and Biggs (1989) used examples of students' descriptions of the process of evaporation from a study by Beveridge (1985) to help exemplify the use of SOLO (Structure of Observed Learning Outcomes) Taxonomy. The purpose of the present study was to investigate the legitimacy of Collis and Biggs' interpretation of Beveridge's data. Students from Years 3-12, were encouraged to provide a full written description of their ideas about "steam", "evaporation" and "water molecule". The findings general support for the SOLO taxonomy and for the value of its use for classifying students' descriptions. However, it appeared that the application of the SOLO taxonomy was not as straightforward as implied by Collis and Biggs. To explain the results more fully it appears necessary to talk about cycles of growth within a mode; more than one unistructural, multistructural, and relational cycle of understanding within the concrete symbolic mode was evident.

INTRODUCTION

The investigation of the development of scientific concepts has received growing attention in the literature. In particular, three focus areas have become apparent:

- the growth of intuitive ideas held by children from an early age;
- their initial conceptual images which may be modified by the teaching process;
- the growth of abstraction of scientific ideas.

Many researchers have studied this acceptance and consequent growth of scientific ideas into children's schema. Most have concentrated on a particular stage of the developmental process, and how children deal with a particular scientific concept. It is important that more data be collected on the way children "learn" about scientific ideas,to help fill in the overall picture of the process of cognitive growth, understanding and learning of scientific concepts.

The particular concepts investigated in this study were those related to the process of evaporation. The work of Piaget (1974) yielded evidence pointing to the pathway which leads from the child's refusal to accept any "passage of matter", to an intuitive explanation involving concrete terms, to an acceptance of evaporation involving a change of state, and finally, to the level in which children described steam as "tiny pieces of water". This last explanation, Piaget felt, involved an understanding of the "corpuscular theory of matter". The pathway he described was age-dependent and involved an increase in the degree of abstraction of ideas.

Osborne and Cosgrove (1983) also studied children's conceptions about the familiar phenomena surrounding evaporation. They believed that children have well-developed ideas about scientific issues such as the event of evaporation, that they bring with them to school from their everyday environment. They used the method of Interview-about-Events (Osborne, 1980). These studies elicited three major findings:

- There exists a high degree of consistency of particular ideas about certain scientific phenomena held by children in similar age brackets.
- Children have their own ideas about scientific phenomena, and these are often quite different from those held by "scientists".
- The results of teaching can be unexpected in that sometimes the outcomes are significantly different from those originally intended.

Beveridge (1985), concentrated primarily on the investigation of the last finding above, ie, that children firmly retained their intuitive, cognitive frameworks used to understand scientific concepts, despite the use of different teaching strategies. The situation he focused on was one in which water held in a container was heated by a gas flame. His preliminary studies implied a lack in understanding by the children both of the non-absorbent nature of the metal pan and of the connection between the steam rising off the boiling liquid and the reduction in its level. His main study failed to provide evidence that further instruction on these two aspects of the disappearance of the water from the heated pan assisted in the induction of an intuitive concept of evaporation.

Children's written descriptions about the process of evaporation, outlined in Beveridge's study, were used as the basis of further research into this field of understanding and learning scientific concepts by Collis and Biggs (1989). They categorised these written responses into their cognitive classification framework, referred to as the SOLO Taxonomy. Collis and Biggs believed that the children's responses were a reflection of their level of understanding of the evaporative process. They provided descriptors for the levels of children's understanding within three developmental stages referred to as modes. Collis and Biggs referred to these modes as Ikonic, Concrete Symbolic and Formal.

The following study was carried out to corroborate the interpretation made by Collis and Biggs of Beveridge's data; whether responses to questions asked about evaporation could be classified into developmental categories.

After a pilot study, the following research questions were chosen:

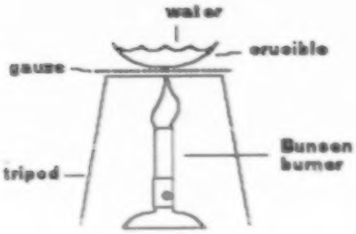
1. Is it possible to categorise a large number of secondary (12-18 years old) students' written responses to three specific questions concerning the scientific concept of evaporation?

2. How do young children's responses to such questions differ from those offered by their secondary counterparts?

3. Does the categorisation of responses reflect the levels and/or modes of the SOLO Taxonomy (Biggs & Collis, 1982)?

The Study

A questionnaire was designed which included the following diagram in order to give students a reference point on which they could build their explanations:



To deduce whether or not the child was working in the science "game", the question referred to an explanation used in a science dictionary. The definition of the phrase "the science game" as it was used in this investigation was: "When the children were able to use and show understandings of scientific terms and language, when discussing everyday events". The words "in as much detail" were also used in the question asked, so the children did not feel restrained.

The written question, given to 190 students from Years 7-12 (aged 12-18) was:

> Imagine you are writing a Science dictionary. Could you describe, in as much detail as possible, what is meant by the following words: steam; evaporation; water molecule.

After each word a large lined space was left to encourage full responses.

To try to obtain data concerning the responses that children who were not working in the science "game" might give, six Year 3 children (age 7 years) were interviewed at length. The evaporative process was the focus concept.

RESULTS

Research Question 1 (categorisation)

The analysis of the Year 7-12 data enabled classification into the following distinct categories (typical student responses are included):

Category A: non-codeable In this category, there were responses which could not be coded. In some cases, it was evident that the student had difficulty writing coherently and the statements made little or no sense. In other cases, the student refused to answer or claimed no knowledge or understanding of the question asked. For example, to the question, "What does water molecule mean?", one Year 7 student responded, "Sweating particles on the floor."

Category B: one feature described In this category the children tended to answer quickly when responding to the questions, i.e. "they put down the first answer that came to mind. A possible reason for these short answers is that students were capable of recalling only one description to answer the question. In the interview situation, when probed, they tended to provide illustrative examples in preference to talking about additional features. When coding responses into this category, the assumption was made that students gave their best answer and it happened to contain one description about the scientific concepts. Typical responses to the question "What does steam mean?": "...a liquid" (Year 8); "...the gas from water" (Year 10).

Category C: more than one feature described Students whose responses were classified into this category gave multiple descriptions when explaining their understandings of the scientific terms. The phenomena of heat, boiling (at a certain temperature) and gas were mentioned in passing, in their explanations as pertaining to the evaporative process. This category seemed to contain subsets which are exemplified as follows:

- Steam - when water gets heated and evaporates it turns from water liquid to air, it is still hot. (Year 7)
- The children placed in this subset recognised that boiling the water was involved for the evaporation of water into steam (a gas) e.g. "Steam is water been heated up so it is boiling. Steam is the gaseous phase of water" (Year 8)

Here the children have considered three features when describing evaporation: heat, boiling and gas. In summary, students in this category have taken some subset of the three features: heat, boiling, gas, into consideration when describing the "evaporative process".

Category D _ generalisations and overview of ideas Linkages and relationships between ideas were a significant characteristic of the responses in this category. The students seem to be able to draw key features of the evaporative process together with the consequence that they are able to provide an overview. Without prompting, the children in this group have introduced the idea of condensation. They appeared to feel that this idea was necessary to fully explain the evaporative process. The children were starting to identify with the process, but at this level of response they were unable to isolate the actual events involved in evaporation, without responding with all the features they could recall being associated with it. For example: "Steam is a form of water, and when you heat water, the water turns into steam. Then, when the steam is cooled, it turns back into water. Just like when you cook peas on the stove, steam comes up, and then when it hits the roof, it turns back into steam" (Year 8)
"Condensation is when the steam turns back into water after cooling it" (Year 10)

Categories E, F, G: process-oriented responses The responses that were allocated to these categories were those where the students seemed to have come to terms with the idea that evaporation entailed a "process". The responses were seen to fall into three distinct subsets:

- Heat was required, and a gas was formed : gaseous state.
- Heat was required, and a gas was formed when a critical temperature was reached: a change of state occured, heat energy was involved.
- As above, but demonstrating an understanding of the molecular nature of matter and the necessity of an input of energy.

The three subsets were allocated separate categories. Although they shared a common thread -- an understanding of an evaporative process -- the differences in the level of understanding were sufficient to warrant separation.

Category E This reflected responses that were process orientated, but at the level where students recognised only that an input of heat was a necessary part of the process; and that a gas was a product of the process. No apparent links between the two were made. The students were able to isolate the evaporative process. Their responses therefore, indicated a clearer idea of evaporation. Examples: "Steam is a gas which is formed by heat." (Year 7) "Steam is a form of water when it gets hot and has to give off a gas and this is steam." (Year 10

Category F Responses classified into this category reflected a greater level in understanding of the process, i.e. that the boiling of water was the intermediate link between the input of heat and the production of gas from a liquid. Students had an understanding of the relationships between the three characteristics. They were able to relate heat, boiling, gas correctly according to cause and effect. Examples: "...when water is at a certain temperature, it evaporates and turns into steam." (Year 12) "Evaporation is caused by boiling the water and turning into steam." (Year 7)

Category G The difference between the level of understanding exemplified by responses coded into this category and those in category F is far greater than the difference between categories E and F. The responses coded into category G showed a depth of understanding that could be classified as a higher order of abstraction of the evaporative process. This understanding of the molecular nature and energy involvement within the evaporative process, requires an extension of the children's interpretation of what is visible, ie, into the area of cognitive abstraction. Examples: "Steam is water changing state from the liquid. The energy put in, changes the state of the liquid. Steam is also the water molecules escaping from the dish in a different form. Steam rises into the atmosphere and soon disappears and can't be seen for the particles in the air mix with it once it escapes" (Year 8) "Steam is water in its gaseous form: molecules of H_2O (one oxygen atom bonded covalently to two hydrogen atoms) moving freely in the air. Evaporation is the process by which water as a liquid is taken into the atmosphere by means of heat, turning the water (as a liquid) into a gas which mixes into the atmosphere." (Year 12)

In summary, the analysis suggests that it is possible to classify secondary students' responses about evaporation. Each category has its own set of characteristic descriptions. Further, the children's verbal explanations remained consistent under probing questioning, during the interview sessions.

Research Question 2 (younger vs. older)

To address this question, six Year 3 (7 Year old) children were interviewed for approximately half an hour each. The decision to interview the children was taken because of their age. In this way, the responses were verbal rather than written, therefore minimising misinterpretation of data due to inability to express themselves in writing.

The interviews revolved around simple diagrams that the children drew as part of their explanation and discussions about everyday occurrences. All three concepts were explained with a heavy reliance on visual imagery. Four features were consistent across the six children:

- They explained their thoughts and ideas accompanied by a large amount of gesticulation.
- Their idea of steam was related to phenomena which they could remember "seeing" in everyday life, for example, "volcanoes erupting", "steam from a train".
- When speaking about evaporation, the idea of "disappearing" was prevalent. To where, could not be fully explained; almost to the point of "It just disappeared"

(non-acceptance/denial), eg, disappearing into the container; disappearing into clouds; or just disappearing.

- They had little idea of what a water molecule was, except, in most cases, they realised that it had "something" added to it before they could drink it. The children were confused about the idea of cause and effect, e.g. when asked what a water molecule was, the children responded with answers such as: "water is made of orange juice", "water is made of raspberry cordial".

Overall, two features stand out. Firstly, the interview was the most appropriate method for extracting information from children, who were unable to express themselves adequately in writing. With this direct interaction, immediate extension of their ideas could be used by an appropriate line of questioning. Secondly, the discussions were image-laden and tended to follow many lines of thought. The children drew on many aspects of their everyday experiences to try to explain the scientific terms, which at times fitted into the science idea of steam, evaporation and water molecule. But, when tested, their responses did not reflect the conceptual understanding of the words, as accepted in true scientific terms. This represented a significant difference between the responses of the primary and those of the secondary children.

With all the data collated and analysed from both the transcripts of the primary children and the questionnaires of the secondary children, research question 3 could be addressed.

Research Question 3 (adequacy of the SOLO taxonomy)

The differences between the primary and the secondary children's responses imply that this research question should be considered in two parts.

Primary Children and SOLO The key characteristics of the children's responses were: they were image laden; their descriptions displayed a lack of cause and effect relationships; they made use of gesticulation. These characteristics clearly reflect the description of what Biggs and Collis referred to as the ikonic mode. This mode is described by Collis and Romberg (1992) as placing "the heavy reliance on imaging, often affect laden"; and displaying a "tendency to make perceptually- based qualitative judgements linked with the capacity for imaging and the continuing interest in sensori-motor activities".

Secondary Students and SOLO When the written responses of students in Years 7 to 12 were analysed, it appeared that they were generally responding in a qualitatively different way to their younger counterparts. The responses of the older students were more precise: they did not rely solely on personal experiences (anecdotal) or their explanation did not need to be validated by story telling or "arm-waving" (in the interview). In addition, there was less reliance on visual images and they were more able to recognise causality in their descriptions. This reflects the ability of the older students to work within the concrete symbolic mode. This level of response implies a growth in the understanding of a process, a gradual shift from concrete reality to the abstraction of ideas.

The discussion which follows considers each of the identified groupings of children's responses A-G, with the SOLO descriptions provided earlier in the paper.

Category A Students in this category were not able to address the question satisfactorily. These forms of response are consistent with those categorised into the prestructural level in the SOLO Taxonomy, ie, non-codeable because of one of the following: denial; tautological; nonsense statements. The inability to code the response may reflect that the children are not yet "into the Science game" i.e. Prestructural.

Category B This level of response is connected to the concrete world by symbols: declarative knowledge. In this category the children have focussed their attention on one specific direct concrete reality, namely a gas, or steam. In the SOLO Taxonomy terms this form is referred to as unistructural, ie the tendency to focus only on a single feature.

Category C This group comprised two subsets of responses. Both share a common quality of describing more than one feature but without an overview of what is happening. This level of response is consistent with the description of the multistructural level of the SOLO Taxonomy.

Category D Responses in this group did provide an overview of the evaporative process to the extent that students were able to bring the ideas of changes of state from liquid into gas by the use of heat and, further, back to liquid by cooling. Their understandings, as reflected in their responses would indicate their ability to generalise scientific concepts. Their conclusions are still relatively reality-based, but show a shift towards an understanding of a scientific process. This overview of what is happening represents the equivalence of the relational level in the SOLO Taxonomy.

Category E There were similarities between group C and group E. In both groups, students focussed on more than one feature. In particular, the emphasis was on heat, but other relevant details were included. The significant difference was that group E suggested that the input of heat was a necessary part of the process, i.e. they were comfortable with the "process" of evaporation. There was an apparent ease in dealing with the abstraction of the concept of the passage of liquid to gas with the input of heat energy. Group E could relate to the ingredients in the overall process of evaporation. Since several ingredients were mentioned in these responses, this category can also be considered at a multistructural level in the SOLO Taxonomy.

Category F The responses in this category reflect understanding of the process of evaporation to the point where all the integral parts of the process are linked to arrive at an overview. The overall process of evaporation is considered in more conceptual terms than was evident in group D. In terms of SOLO Taxonomy, this group would be considered at the relational level.

Category G Here, there seemed to be a large jump in the level of understanding and the ability to manipulate complex abstractions. The responses appeared to reflect an understanding of molecular theory and, in some cases, an understanding of the kinetic theory of gases. This is consistent with formal thinking. The children are able to bring other ideas into their explanation of evaporation, e.g. the molecular nature of water, the heat and kinetic energy component of change of state, to fully describe the process. This ability to generalise and hypothesise would place these responses into the formal level of the SOLO Taxonomy.

These results are depicted in Fig. 1.

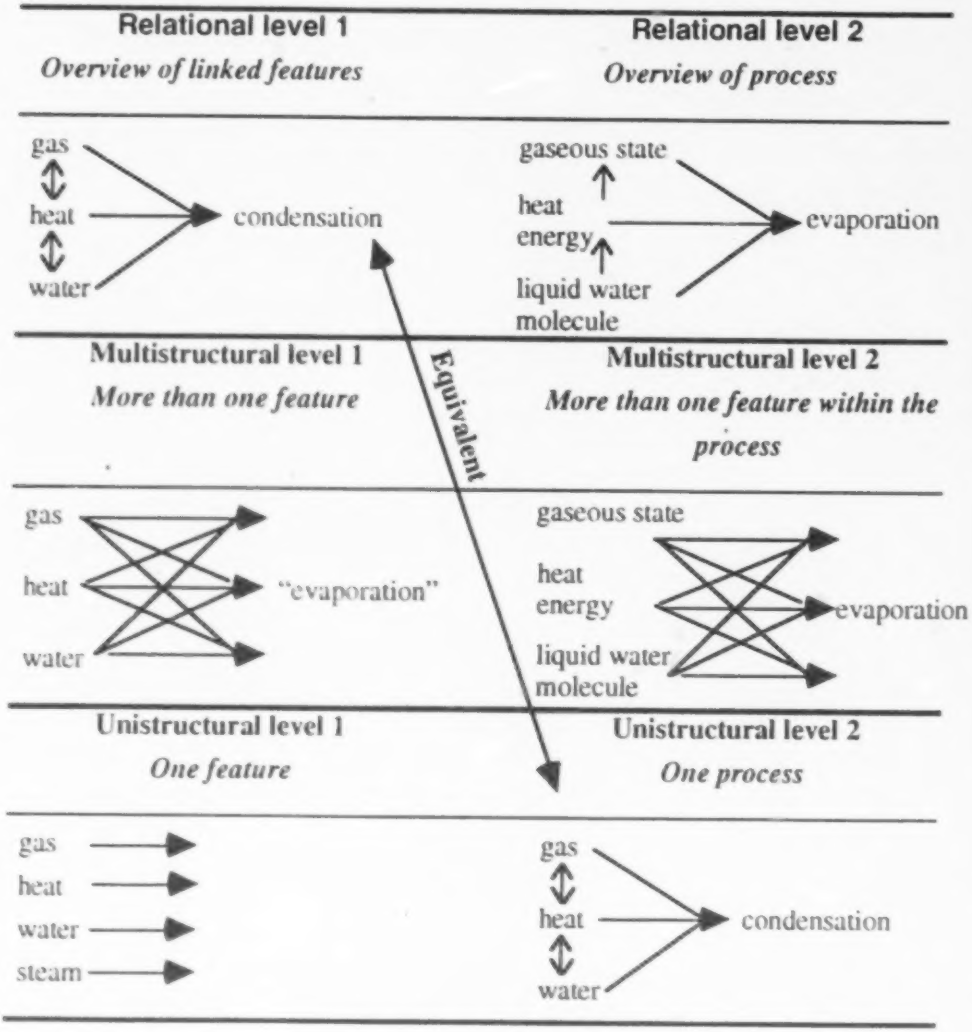

Relational level 1
Overview of linked features
Relational level 2
Overview of process
gas
heat
water
condensation
gaseous state
heat energy
liquid water molecule
evaporation
Multistructural level 1
More than one feature
Equivalent
Multistructural level 2
More than one feature within the process
gas
heat
water
"evaporation"
gaseous state
heat energy
liquid water molecule
evaporation
Unistructural level 1
One feature
Unistructural level 2
One process
gas
heat
water
steam
gas
heat
water
condensation

Fig. 1: details of cycles in concrete symbolic mode.

It would appear that a single cycle of levels provides too simple an account of the concrete symbolic mode. The depth of analysis and the concept under investigation would seem to determine the number of cycles which would present themselves. In this study two cycles became apparent. There was an increase in students' powers of abstraction and conceptualisation from the first cycle to the next which reflected the increased complexity of their responses, i.e. from the mention of a "gas" in the first cycle to the use of the term "gaseous state" in the second cycle.

It may be suggested that the early cycles are ones in which students acquire basic concepts: students react to reality as they perceive it. This part of cognitive development is thought to be necessary both in a formative and supportive role for the growth in concepts which follow. The increase in understanding from the point where the students recognise that "gas" is part of what is referred to as evaporation, to the point where they are able to "get underneath" the idea of a gas and explain it in terms involving "energy" and "molecular state". The results from this study support this conclusion, as the students grapple with the transition from the basic understandings that underpin the more demanding abstract ideas concerning evaporation.

CONCLUSION

Clearly, students' responses can be classified in terms of the SOLO Taxonomy. However, this finding is not without its problems. Firstly, although the primary children interviewed were responding in the ikonic mode, the data did not offer any indication of different levels. An additional study would need to be designed and undertaken, if a detailed description of their responses at the various levels of the ikonic mode were to be achieved.

Secondly, the groupings of responses B-G by the secondary students were consistent with the concrete symbolic mode, since generally the responses had the following characteristics:

- a move from the perceptually evident to the abstracton of ideas;
- the ability to ascribe causality correctly;
- a growth in understanding of the process involved within the concept known as evaporation.

However, the responses could not be interpreted directly into the SOLO framework, as there were different depths of understandings reflected by the responses within the same mode. This could be described by more than one unistructural, multistructural, relational cycle.

A number of issues need to be addressed in the next phase of the investigation, viz:

- Does this pattern of cognitive growth appear when other scientific concepts are being studied (e.g. digestion)?
- Is the increase in level of understanding of abstraction descriptive or prescriptive?
- How can the findings of this study be related to the teaching of specific concepts in the classroom?

This last point is most important if this theoretical model is to be used effectively in curriculum development and evaluation and development of appropriate classroom strategies. The SOLO Taxonomy may indeed be an important tool for teachers, curriculum analysts and educational researchers. It has the potential to provide these professional groups with the means to comprehend children's understanding, plan instructional sequences and analyse how children acquire concepts.

These findings, although from an early stage of research, go part of the way to give teachers a framework for considering the way in which children grow in their understanding of scientific concepts.

REFERENCES

Beveridge, M. (1985). The development of young children's understanding of the process of evaporation. British Journal of Educational Psychology, 55, 84-90

Biggs, J.B. & Collis, K.F. (1982). Evaluating the quality of learning: the SOLO Taxonomy New York: Academic Press

Collis, K.F. & Biggs, J.B. (1989). A school-based approach to setting and evaluating science curriculum objectives: SOLO and school science Australian Science Teachers Journal, 35 (4),

Collis, K. & Romberg, T. A. (1992) Assessment of mathematical performance: an analysis of open-ended test items. In M. C. Wittrock & E. L. Baker (eds) Testing and cognition New Jersey: Prentice Hall.

Osborne, R. (1980). Some aspects of the students' view of the world. Research in Science Education, 10, 11 - 18.

Osborne, R.J. & Cosgrove, M. (1983). Children's conceptions of the changes of state of water, Journal of Research in Science Teaching, 20 (9), 825-838

Piaget, J. (1974). Understanding causality, New York: Norton

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BECOMING A SCIENCE TEACHER: FIRST YEAR TEACHERS' APPROACHES TO LEARNING ABOUT TEACHING.

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ABSTRACT

This paper discusses some of the issues arising from the first year of a longitudinal study into the career development of science teachers. It deals with the influences on, and approaches to, teaching by first year science teachers. Eighteen science graduates who had completed a Diploma in Education in 1990, were interviewed about their first year's teaching experiences. The participants explored issues ranging from the influences on their approach to teaching, student learning, determinants of a good lesson, the role of pre-service teacher training, and teaching as a career.

BACKGROUND

Zeichner and Tabachnick (1981) describe the attitude shift that student teachers make when they move from University course work to school teaching. They highlight the regression in student attitudes toward more traditional viewpoints as they become immersed in the profession. Yet, as a teacher educator, I have often viewed student-teachers as agents of change in schools, introducing new ideas and enthusiastically engaging students in learning. They often display a great desire to teach, to help their students to learn and to 'make a difference'. Also, the occasional meeting with previous years' students led me to believe - through anecdotal evidence - that this persisted into their early years of teaching.

It is from this perspective that this research project was initiated. It is an attempt to understand better the development of the career of science teachers and to explore some of the factors which influence and shape their pedagogy.

INTRODUCTION

Until the mid-1980's, a large proportion of the literature on beginning teachers focused on teacher development in relation to technical competence or expertise. Veenman (1984) reviewed empirical studies of beginning teachers which helped to highlight some of the technical problems encountered by beginning teachers. Although it is important for teachers to develop an array of teaching techniques which they can implement in the classroom, the strength of good teaching is in the pedagogical reasoning which accompanies classroom actions (Berliner, 1986; Shulman, 1987). As an empirical approach may miss instances of the pedagogic competence that transcends technical rationality (Stark, 1991), this study aimed to explore pedagogy from the teacher's perspective.

With this in mind, one focus for this research project was to investigate the influences on beginning science teachers' classroom practice. But what does one look for or question to delve realistically into this area of research?

Brookhart and Freeman (1992) highlighted the link between teaching and learning and how a teacher's understanding of these influence the classroom activities.

> Teachers' conceptions of the teaching and learning processes and their beliefs about students, classrooms, and subject matter will have an important influence on what they do in the classroom. (p.49).

Therefore, attempting to understand teachers' conceptions of their own teaching and their views of student learning became important elements of this study.

METHOD

Stark (1991) explored the beginning teacher experience through a phenomenological journey with two first year teachers. The study forced her to question her assumptions because of the methodology she employed.

> Empirical methodologies...tend to place less emphasis on the importance of human feeling, cognition, emotion, and perceptions, and thus, they may disregard a teacher's being-in-the-world. If we ignore a teacher's being, how can we seek an understanding and construct meaning out of what the experience is like for that person? (p. 295-6).

I wanted to understand the beginning science teacher's experience. To do this required an approach that would allow participants an opportunity to think about and convey their views, thoughts and experiences of teaching and learning. In order to do this I sought the involvement of recent graduates.

Twenty science graduates, who had completed a Diploma in Education in 1990, were asked to consider being interviewed about their first year's teaching experiences; 18 agreed to be involved. The size of the cohort was limited only by the number of students known to be in full-time employment (and able to be contacted) in Victoria in 1991.

Of the participants, thirteen were teaching in Melbourne metropolitan schools and five in country schools. All of the country placements were in Government schools, while twelve of the metropolitan placements were in Independent or Catholic schools.

Teachers were interviewed at their schools - at a time which was convenient for them - late in the second semester of 1991. Participants were sent a copy of the interview protocol two weeks prior to the interview. This was designed to give them an opportunity to think about the questions before the interview so that their responses might be more considered.

Interviews were generally of one hour's duration and participants explored issues ranging from the influences on their approach to teaching, determinants of good (and not so good) lessons, student learning, the role of pre-service teacher training and teaching as a career.

These interviews were designed to tease out some of the influences on science teachers' experiences as seen by the teachers themselves. As they were exploratory and hypothesis-generating, interviews were conducted in two phases. The first phase involved interviewing a sub-set of the participants, then reviewing the data for major themes and issues. In the second phase, the remainder of the participants were interviewed. At this time, the interviewer focused on developing and testing the significance of the issues and themes which emerged during the first phase.

All interviews were audio-taped, transcribed and then coded and analysed using the computer program NUDIST, a qualitative data analysis program which enables the user to sort and recall coded segments of data so that responses to particular issues or questions from different individuals may be more readily compared.

FINDINGS

In analysing the data, I was interested in developing an understanding of these science teachers' perceptions of and influences on teaching and learning. Therefore, during analysis there was a concentration on four pivotal questions:

* How do the participants perceive their own teaching?
* What do they see as influencing their teaching?
* What evidence do they have to support their views?
* How does their idea of teaching match their view of student learning?

By searching for the answers to these questions, I had hoped to develop a comprehensive picture of each individual's understanding of his or her approach to teaching. It would then be one strand of the study to follow up in subsequent years. It was hoped that this would shed more light on how science teachers' approaches to teaching shift and what factors lead to such shifts.

As became apparent during the analysis of the data, understanding approaches to teaching and learning is more difficult than it may initially appear. Although I had developed ideas about individuals' approaches to teaching, ways of grouping these approaches and likely implications for further study, the data continued to 'speak back to me' (Schon, 1987) in new and different ways as I struggled to develop a cohesive picture. The following report is an attempt to explain these events as the picture developed.

Approaches to teaching: Determining each individual's approach to teaching science led me to develop four broad categories. They were determined by allocating common responses or descriptions of lessons into groups. The four broad perspectives which emerged included a:

* knowledge-based approach,
* skills-based approach,
* hands-on/real world approach, and,
* meta-cognitive approach.

The knowledge-based approach is characterised by an expressed need to transmit the information that is regarded as important in developing a 'common' understanding of a concept for the students. This approach includes practices such as note-taking and other related text and comprehension activities. It was often described as more traditional teaching. For instance:

> How would you describe your approach to teaching science?
>
> Fairly conventional, I think. I believe that I've just always found that if you don't give a certain amount of information nothing sinks in so I like to give blackboard notes...With the Year 11s there was a lot of theory because there was just so much to cover and we had prac once a week....

The skills based (or process) approach is characterised by a concentration on problem-solving skills similar to that described by Cussans (1989). Through this approach, an appreciation of how something works is fundamental to developing an understanding of a concept. Therefore, content is used as a vehicle for a process approach to science teaching and learning. Observation, inference and hypothesis testing are seen as important skills to be developed in this approach.

> I've told all my boys - and even the parents - that even if they leave the year and forget half the material that they've learnt, I wouldn't be concerned, but the skills that they develop are important...

The hands-on/real world approach focuses on creating episodes (White, 1988) where the context is a trigger for student learning. It also attempts to relate scientific concepts or principles to applications in the real world so that students will see learning as relevant.

> ...most times I try to relate it to the real world. I try to set up experiments where the theory behind what we're doing in science relates to the practical world.

The meta-cognitive approach is dependent on students recognizing or identifying their own cognitive processes (Baird & Mitchell, 1986). Through this approach, students are encouraged to accept more responsibility for their own learning and to be more aware of their own needs in developing an understanding of a concept.

> I try, I do try to do things that encourage them to learn for themselves and draw their own conclusions....trying to get them to question why.

With these four categories determined, the next step was to assign teachers to a category from descriptions of their approach to teaching. Table 1 illustrates this allocation.

Having identified these four groups, I attempted to review the data to determine the belief structures (Fenstermacher, 1979) which underpinned the teaching approach. But as I analysed the data, it became increasingly apparent that most of the teachers aimed for similar outcomes from their teahcing. They spoke of trying to spark an interest in their students and to build their confidence so that they were motivated to learn. Yet to me, the four categories were based on factors other than just increasing the level of student interest. To try to resolve this dilemma I turned to the teachers' views of student learning.

TABLE 1
FIRST YEAR TEACHERS' PREDOMINANT APPROACH TO TEACHING SCIENCE

APPROACH	TEACHERS (N)	TEACHERS (%)
1. Knowledge-based	2	11%
2. Skills-based	3	17%
3. Hands-on/Real world based	10	55%
4. Meta-cognitive based	3	17%

Views of student learning: In the interviews, participants were asked how they thought students learnt. Typical responses to this question included by doing, by relating what they are learning to what they already know, through curiosity, by seeing the relevance of what they were doing, by questioning what they were doing and by acquiring knowledge.

They were also asked what they would change to improve student learning. Common responses to this question included creating more episodes to aid recall, challenging students to think more, doing more laboratory work, creating opportunities for students to want to learn and changing students' misconceptions.

I then compared these responses to the teaching approaches. By juxtaposing these two fields I had hoped to find a relationship between teaching approach and views of student learning. I expected the belief structure about student learning to have an important bearing on the way the teachers approached their pedagogy.

What I discovered was that many of the teachers had multiple views of student learning which were influenced by a number of factors. Of these, the degree of familiarity with the content area and the year level to be taught were significant. In some instances, teachers stated that their approach varied as a result of these factors. Also, some teachers recognized the difference between what they do and what they would like to do.

My original notion that teaching approaches might be linked to particular views of student learning was tested. In some cases, the data seemed to 'fit' the hypothesis, but exceptions were appearing.

> I prefer to have small groups doing things and exploring, experimenting and hypothesizing about what they think is going to happen, rather than, "copy this down and regurgitate it to me." So Science is an area where it can be just so much more hands-on work than any other subject and that's the kind of way I approach it. So, "you do it and you tell me what you think is happening." Discovery learning, yeah. It doesn't always work again depending on personalities and things like that...I prefer to work that way, particularly with junior classes I find they prefer that as well. Whereas I don't know if say the

> 10s work better that way. I think the lower the Year level the better off you are with that kind of thing.

Making sense of the data was becoming more difficult and frustrating. If exploring, hypothesizing and paraphrasing are important, why would they be appropriate at one year level but not another? Individuals' views of teaching and learning must be more fluid than I had originally envisaged. I faced the difficulty of trying to reconcile multiple views of approaches to teaching and learning that in some cases appeared contradictory. To understand these views better, I paid closer attention to the factors that teachers suggested as influences on their pedagogy.

Influences: Some of the factors suggested as influencing an individual's approach to teaching included: attempting to create greater student interest, making learning more enjoyable, and the teaching styles of previous teachers. These responses are not surprising, perhaps even expected. However, 50% of participants stated that Dip. Ed. was a major influence on their pedagogy. Not only was it cited as an influence, but specific examples of sessions, courses or individual lecturers were given as illustrations to further validate the point.

> I thought the course was great, I thought it was a really good course, it was so much better than the Engineering course I did...For a lot of the lectures we were having the teaching techniques modelled to us in the actual substance of the lectures. We were having teaching techniques modelled and that was very valuable.

Responses like this caused me to re-conceptualise what I had been thinking. The Dip. Ed. influences, still relatively fresh in these teachers' minds, had offered a smorgasbord of teaching strategies. They had experienced many of these strategies as learners and had therefore noted them as useful teaching tools.

> ...the science course was well planned, and one particular part of the science course which I enjoyed and I use quite a bit now, is to do activities called POEs [Predict, Observe, Explain, White & Gunstone 1992]...actually it's a help for me, it shows me if they understand what's going on or not.

> I did something in chemistry called the Atoms party. I've used that heaps and it's been really good. And drama things that I've used in science, like getting kids to write things and using crosswords and different things like that...We had one session just on all different things like that that you can use...Oh I remember too one thing where you, instead of just giving them notes on the board, like giving them a segment of notes but cutting it all up and jumbling up and getting it back together. I did that. Yeah, actually, I have used a bit more than I thought I had.

> The Method classes, I saw from the beginning as being a way of collecting information, collecting strategies and collecting a variety of tactics to use in teaching.

What I had not paid enough attention to was why a particular teaching strategy might be used. The Dip. Ed. experience opened up new ways of approaching teaching, but I needed to know if this corresponded to a better understanding of learning.

Putting the pieces together: The connections between the data -- approaches to teaching, views of student learning and influences -- were still hazy. Individuals could fit neatly into categories in one context then change - sometimes into contradictory categories - in another. It was readily acknowledged that confidence with content and the year level taught were influencing these shifts, but these alone did not seem to resolve the dilemma. There seemed to be something missing. I was still clinging to the view that teaching strategies based on a learning theory hold the greatest potential for effective learning (Appleton 1990) and assumed that this view would apply to teachers generally.

The picture became much clearer during a discussion about the PEEL project (Baird & Mitchell, 1986) with Jeff Northfield. What I was struggling to recognize was the gradual emergence of a purpose for the use of particular teaching strategies by each of these beginning science teachers. I could see shifts from one teaching approach to another but could not align the teaching strategy with a view of student learning that made the shifts sensible to me.

Studying individual descriptions of teaching episodes, exploring the pedagogic moment (van Manen, 1992) highlighted that which had been eluding me.

> Last physics class, we were teaching Newton's Laws. We were trying to get the hang of how it takes a force to change a velocity of a mass, so a mass even without any friction you need a force to get it moving, and, the relationship between how the force would produce different accelerations on a mass or different masses for the same force would result in different accelerations. And so we had a POE going...
>
> So we set an aisle of tables running right up the middle [of the classroom] and produced a couple of ice blocks, kilogram ice blocks that we'd moulded in the two litre milk containers with bits of rope embedded in them...we wet the table down with some dishwashing liquid.
>
> Then the students using spring balances, apply constant forces to the ice blocks and accelerate them up and down the table and time it and compare it to the rates for acceleration and so forth...You run it along faster and then you run the length of it pulling this ice block and you've got this kilogram of ice hurtling awfully fast...you break it up every go and you say well what's happened and what's going on here, the students get keen. It's a co-ed classroom so you have a little bit of boys trying to not look dumb in front of the girls and the girls trying to look smarter than the boys and so you get a little bit of the natural electricity there, you can get that going. Students are making predictions and then you see some of them are wrong and some of them are right as you walk around. Then after the demonstration you have an argument ensuing between the student explaining no it did this, I saw it do this because so and so and I saw it do this because so and so.

> Then they point out that the observation shouldn't actually correlate with their predictions...so you get lively discussions about the material...so the resolution with the participation of the students seeing and throwing their ideas around and expressing their ideas, that's important.

The richness of this description illustrates a teacher with a good understanding of how he wants to challenge his students' understanding of a concept. The use of the P.O.E. as a teaching strategy to do this highlights his desire to do more than just give them the right answer.

There are many examples like this from many of the teachers. As I started to review them again, I recognised an important difference between some of them. On the one hand, a teaching strategy could be used as a way of gaining student interest and involving them more in the lesson. On the other, it could be used to help students challenge their understanding of a concept and construct new meaning. Considering the conversation with Northfield, I believed that I was observing science teachers who were starting to construct new meaning in their teaching. Figure 1 is a schematic representation of this view.

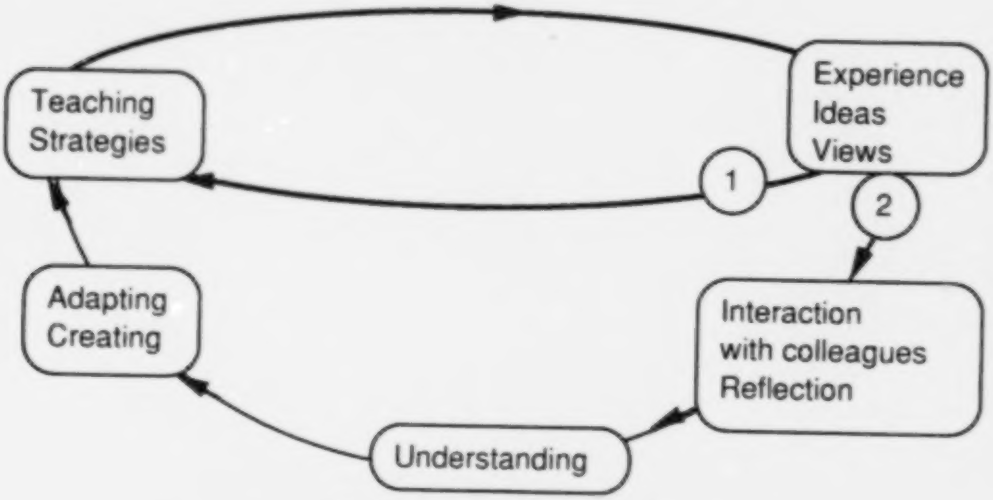

Fig. 1: Two cycles in developing an understanding of teaching.

In Fig. 1, two approaches to the use of varying teaching strategies are portrayed. The first depicts the use of teaching strategies in order to combine experiences, ideas and views in the teaching. An outcome of this approach might be the encouragement of greater participation and interest amongst students. The second is a path towards greater understanding of the teaching strategies. This involves interaction and discussion with colleagues about the approach, reflecting on the experience in terms of what happened and why, and, adapting and/or creating new teaching strategies as a result of an enhanced understanding.

Teachers on the inner track are experimenting with teaching strategies to develop a diversity of approaches to teaching. However, these approaches might be used only in a given lesson or specific content area and simply be revisited when that unit is taught again.

Teachers on the outer track are considering the purpose of the strategy and applying it to new and different situations as they develop ways of enhancing student learning.

This is not meant to belittle the efforts of those who are using teaching strategies as a means of creating student interest. On the contrary, I believe it is heartening to see beginning science teachers prepared to try new and different approaches to classroom teaching. These participants do not seem to have had the effects of University teacher education washed out by the school experience.

Perhaps those who are developing a greater understanding of their own pedagogy are also those who are starting to align their teaching to a view of student learning. It was evident from the data that such teachers were not particularly concerned with classroom management. They appeared to have moved from concerns about teaching to concerns about learning.

Although many of these science teachers displayed varying approaches to their teaching, most could be categorised (Table 1) by their own description of their predominant approach to teaching. In most cases, my interpretation of other related data (eg. their descriptions of common classroom teaching practice) reinforced their allocation to a particular category. However, the teachers who seemed to be on the second track of Fig.1. were those who I had categorised as adopting a meta-cognitive approach to teaching. They thought about their teaching and student learning in ways which extended beyond simply creating variety or interest.

> I went to a really interesting seminar...that I found helpful and I also saw that I've got a number of flaws in the way I have been thinking things, doing things. I've been thinking I've been fairly successful in having a structured discussion and that kind of thing in a classroom and after having seen that I thought, "Well I've probably lost three quarters of my class here and I've been engaging twenty-five percent quite energetically and enthusiastically but the other ones could be doing anything. I haven't had them engaged...When I go back and restructure what I'm doing I'll be looking very carefully at the way I can work that into my lessons so that I've got everyone doing something. But more likely in small group work rather than larger classroom discussions. I find seminars like that very useful...I think it's really important that you have to make time for it because I don't want, particularly in my first year of teaching, to get stuck into a rut.

These teachers reflected on their teaching. They wanted to improve their pedagogy but, importantly, they endeavoured to do this by consciously attempting to create a better learning environment.

FUTURE DIRECTIONS:

This project will continue to follow the development of these science teachers. It will investigate the conditions which lead to changes in their pedagogy and attempt to trace these shifts through their experiences. As this is to be a longitudinal study, the ideas that are generated by the research in one year need to be tested with different teachers in various settings. It is hoped that another group of beginning science teachers will be studied in 1992 to test the hypothesis outlined in this paper.

This project provides an opportunity to better understand the development of a science teacher's thinking about teaching and learning. It is hoped that this group of science teachers will be followed for a number of years so that their story might be told.

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REFERENCES

Appleton, K. (1990). A learning model for science education: Deriving teaching strategies. Research in Science Education, 20, 1 - 10.

Baird, J.R. & Mitchell, I.J. (eds.) (1986). Improving the quality of teaching and learning: An Australian case study- the PEEL project. Melbourne: Monash University.

Berliner, D.C. (1986). In pursuit of the expert pedagogue. Educational Researcher, 15 (7), 5 - 13.

Brookhart, S.M. & Freeman D.J. (1992). Characteristics of entering teacher candidates. Review of Educational Research, 62 (1), 37 - 60.

Cussans, B.A. (1989). Problem solving: A way of promoting scientific skills and processes. In D. Bentley & M. Watts (eds.), Learning and teaching in school science. Milton Keynes: Open University Press.

Fenstermacher, G.D. (1979). A philosophical consideration of recent research on teacher effectiveness. In Shulman, L.S. (Ed.), Review of Research in Education 6, 157 - 185. Itasca, IL: Peacock.

Schon, D. (1987). Educating the Reflective Practitioner: Toward a new design for teaching and learning in the professions. San Francisco: Jossey-Bass.

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57 (1), 1 - 22.

Stark, S. (1991). Toward an understanding of the beginning-teacher experience: Curricular insights for teacher education. Journal of Curriculum and Supervision, 6 (4), 294-311.

van Manen, M. (1991). Reflectivity and the pedagogical moment: the normativity of pedagogical thinking and acting. Journal of Curriculum Studies, 23 (6), 507 - 536.

Veenman, S. (1984). Perceived problems of beginning teachers. Review of Educational Research, 54 (2), 143 - 178.

White, R.T. (1988). Learning science. Oxford: Blackwell.

White, R.T. & Gunstone, R.F. (1992). Probing understanding. London: Falmer Press.

Zeichner, K.M. & Tabachnick, B.R. (1981). Are the effects of university teacher education 'washed out' by school experience? Journal of Teacher Education, 22 (3) 7 - 11.

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DEALING WITH GRAPHIC OUTPUT FROM DIAGRAM PROCESSING TASKS: APPROACHES TO CHARACTERISATION AND ANALYSIS.

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ABSTRACT

The current relative lack of detailed knowledge about how learners interact with the types of diagrams used in instructional materials is partly due to the research difficulties in characterising the cognitive structures and processes involved in these interactions. One of these difficulties arises from the lack of research tools specifically designed for the collection and meaningful analysis of relevant data. This paper describes computer-based approaches developed to analyse and characterise graphic output produced during diagram processing tasks.

INTRODUCTION

Although diagrams are fundamental to the presentation and explanation of subject matter in science instruction, little is known about the processes that occur in a person's mind as this form of information is being interpreted. Despite the common assumption that a 'picture is worth a thousand words', compelling theoretical reasons for why diagrams should facilitate learning (Larkin & Simon, 1987), and accumulating empirical evidence that diagrams can improve conceptual recall and problem solving (Mayer, 1989; Mayer & Gallini, 1990), our understanding of the way people mentally deal with diagrams and other explanatory pictures is as yet in its infancy. Research in the general area of pictorial processing suggests that even when instructionally-useful visual information is provided, it cannot be assumed that viewers will process it appropriately (e.g. Scevak & Moore, 1990; Salomon, 1989). One of the challenges in researching this area is the essentially hidden and apparently 'instantaneous' nature of visual interpretation processes. These characteristics make investigation of how the processing takes place far more difficult than the investigation of other more overt and prolonged activities, both in terms of data collection and analysis.

This paper deals mainly with computer-based techniques developed to address the problem of analysing graphic output produced in the course of investigations of diagram processing. Although these investigations involved a diagram processing task, the focus of the research of which they formed a part was not concerned with diagram processing per se. Rather, this experimental diagram processing task was used as one of a number of approaches to characterising the fundamental mental representation of a particular diagram genre. The nature of the underlying mental representation that an individual possesses for a particular knowledge domain has been shown to exert a profound influence on the way he or she deals with information from that domain (e.g. Anzai & Yokoyama, 1984). The paper also reports the use of static and dynamic computer graphics to enhance the effectiveness with which findings about temporal patterns in diagram processing activities can be communicated.

Diagram Processing Indicators

One form of behaviour that has been suggested as an indicator of the mental processes people use in dealing with diagrammatic material (and thus their underlying mental representation of that material) is the way the markings constituting a diagram are explored by a viewer (Lowe, 1989). Information about exploration patterns is one piece of external evidence for what may be controlling the way the diagram as a whole is being processed. Before considering the way people explore pictorial material, it is useful to reflect on how they explore text written in a language such as English. The standardised left-to-right, top-to-bottom sequential patterns which characterise normal text reading behaviour are well-established and generally applicable forms of exploration that are usually disrupted only under special circumstances, such as when the reader is engaged in skimming, scanning or very focussed forms of non-sequential search. In contrast, no similarly constrained exploration patterns appear to exist across pictorial materials in general. There is evidence that individuals can differ greatly in the way they explore a page consisting of pictorial material (Loftus & Mackworth, 1978; Lowe, 1991; Yarbus, 1967). Factors such as the way the pictorial material has been characterised to the viewer, the task that the viewer has been set and the viewer's expertise with regard to the subject matter all appear to influence the order in which different regions of the display are inspected. The first two of these factors are examples of external contextual influences on diagram processes while the third provides an internal context that the viewer brings to processing tasks by way of her or his mental representation of the type of pictorial material involved.

A number of techniques have been developed by the author in recent years to probe the way graphic markings are explored during processing of diagrammatic material (Lowe, 1989, 1990, 1991). These techniques have been designed to address the problems referred to above in collecting data on diagram processing as a way of characterising the mental representation of a particular diagram genre. They use a variety of different approaches to externalise and 'slow down' aspects of the diagram processing activity and typically require subjects to produce some form of graphic output. While a range of analytical approaches and procedures exists for dealing with verbal and textual output generated from human performance, suitable tools are not available for analysing output from graphics-based tasks. The availability of simple yet flexible graphics programs on the Macintosh computer indicated that it may be suited to the development of appropriate analytical techniques. A survey of the various black and white drawing and painting programs available at the time the original analytical techniques were being developed showed that Macpaint II had the most effective combination of characteristics for dealing with the data being generated from this diagram research.

WEATHER MAP PROCESSING TASK

The series of diagram investigations for which the techniques described here were developed compared the way meteorologists and non-meteorologists performed a weather map processing task. The particular investigation that will be referred to during this paper is described in detail elsewhere (Lowe, 1991). Its goal was to study differences in the mental representation of weather map diagrams by subjects with different levels of expertise in the diagram's subject domain (meteorology). Briefly, it involved subjects drawing a copy of a weather map onto a blank outline map of Australia and later producing a drawing of what they could recall of the meteorological markings that were present on the previously copied map. The subjects were videotaped as they produced each of the drawings. The data collected reflected both the subjects' processing activities as they drew the maps and the products of these activities in the form of sets of copied and recalled weather map markings. The focus in the first part of this paper will be upon the characterisation and analysis of these static products. This will be followed by a description of alternative ways of communicating results of the analysis of the processing activities in order to reflect the dynamic nature of the information.

DATA ANALYSIS

The analysis examined differences in way the weather map diagrams were drawn by the different types of subjects. Of particular interest was the extent to which the products from each of the subject groups reflected domain-specific (meteorological) and domain-general (visuo-spatial) approaches to their processing of the meteorological markings. These approaches can be taken respectively as indications of deep and superficial levels of processing of the given information in terms of the type of underlying mental representation they reflect. Previous research comparing individuals with different levels of expertise in a particular subject area indicates that experts mentally represent information in terms of its deep stucture while novices focus upon its surface features (Chi, Glaser & Farr, 1988). A finding of different levels of processing of weather map diagrams by meteorologists and non-meteorologists would suggest underlying differences in their mental representations of these diagrams.

Basis for Analysis

The measures used for the analysis were chosen such that they could encompass both the superficial visuo-spatial characteristics of the markings produced and their deeper meteorological significance. The visuo-spatial characteristics of the markings are those that allow them to be recognised in purely graphic terms without relying on any specialist semantic knowledge. For example, a particular closed circulation isobar shown on a weather map could be described quite clearly by a person knowing nothing about meteorology simply by specifying its size, shape and position on the map. This would enable it to be identified unambiguously amongst a whole map full of meteorological markings on the basis of its physical characteristics. This basis of characterisation is domain-general in that it could be applied to any graphic entity, quite independently of the particular subject matter it was supposed to depict. This approach to analysis is partly derived from the framework suggested by Mandler and Johnson (1976) for the characterisation of complex pictures.

In order to characterise the markings in a manner which also encompasses their domain-specific character, the analysis must be consistent with their meteorological significance. A visuo-spatial characterisation of the closed circulation isobar (referred to above) as 'a medium-sized pear-shaped object lying on its side that is near the bottom of the map just under Australia', is simply not good enough. The area (size) covered by such a marking has important meteorological ramifications with regard to its effects on the geographic region concerned; its pear-like shape may be an indicator of the likely meteorological changes that will occur in the near future; its position (centred in the Great Australian Bight) is a classic indicator of particular aspects of a stable summer weather pattern. These types of meanings overlay the purely physical characteristics that are involved in a simple visuo-spatial representation of the markings and are peculiar to the domain of meteorology. They also demand an attention to detail that goes beyond what would generally be sufficient for an an informal, everyday visuo-spatial representation of the graphic material. In particular, subtleties in shape and position require further elaboration.

Analysis Measures

The analysis used for this investigation determined the accuracy with which subjects had copied or recalled the size, shape and position of the markings on the map. To deal with the degree of attention to detail required to capture the meteorological significance of the characteristics of the markings, shape and position involved more than one measure. For the shape of markings, measurements were made of both their general proportions and details of their internal convolutions. In addition, measurements were made of both the general positioning of markings and the specific location of their intersections with the display border and outline of the Australian continent. Figure 1 shows how the various measures were operationalised.

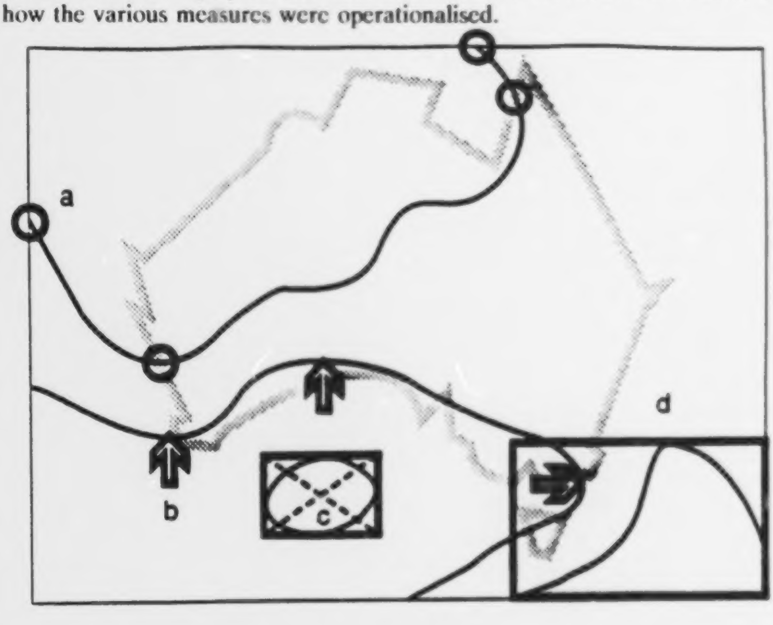

Fig. 1 Analysis of map markings
(a) Intersections (with border or map outline)
(b) Arch points (internal convolutions)
(c) Position (centre of enclosing rectangle)
(d) Area and proportion (from rectangle sides).

It can be seen that a number of these measures involved some degree of approximation. This was in part due to the limitations of the graphics program used for the analysis. However, pilot studies had shown that the analysis was sufficiently sensitive to detect the broad-scale differences that were of interest in this investigation.

Product Analysis

Subjects' drawings were scanned to produce graphics files prior to analysis. The original map display was used to prepare a transparent template that consisted of a blank outline map with the features that were salient in the analysis marked by lightly shaded dots. These dot templates were used as standards against which deviations on the subjects' drawings were measured. The diameter of the dot was the same as the length of the cross cursor to facilitate location of the cursor in the centre of the dot during the measurement process. As shown in Figure 2, each dot was accompanied by a code that identified the individual graphic element from which it was derived.

Each of the scanned subject drawings required some preparation before it could be used with the measurement templates. This preparation involved establishing the position of the points on the subject's drawing that corresponded to the standard dots on the measurement template. For intersections of elements with the display border and the map outline, no special preparation was necessary. However, indications of other types of characteristics required either the addition of further markings to the subject's map before scanning, or preliminary use on the scanned image of graphics tools in the Macpaint program. To obtain a measure of the accuracy with which convolutions in graphic elements were rendered, two independent judges marked with a cross each of the peaks and troughs in the elements present in the elements drawn by the subjects. These markings were averaged (before scanning) to establish what were termed 'arch points' within the markings. The general positioning of elements was determined by using Macpaint's rectangle tool to pull a minimum enclosing rectangle around each of the elements. The rectangle's centre was then located using diagonals. The lengths of the sides of these enclosing rectangles were also used to provide an index of the general proportions of each element and the area it covered. These lengths were recorded manually from the display in Macpaint's cursor position box.

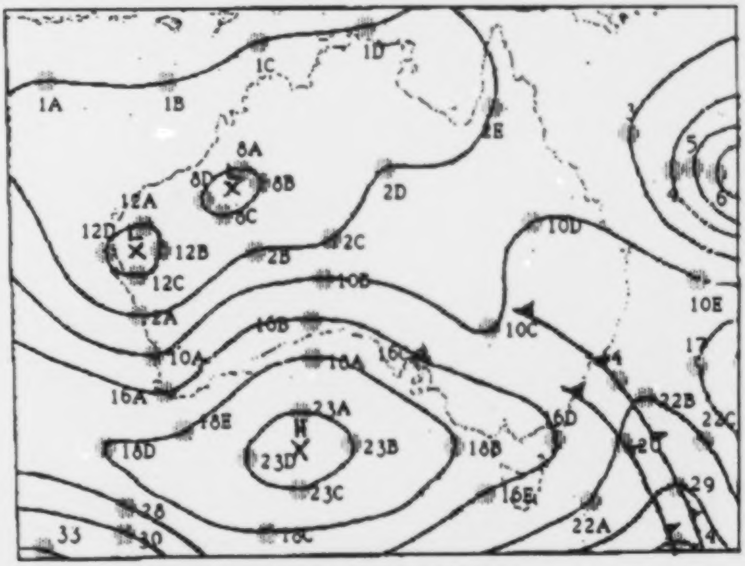

Fig. 2 Dot template for arch points.
Template superimposed on original markings and shows identification codes.

Once the subject's maps had been prepared, deviations of the intersections, convolutions (arch points) and centre positions of each element from the original were determined. This involved using the 'cut and paste' facilities available on the Macintosh to first paste a copy of the transparent dot template for the particular characteristic concerned onto a copy of the previously prepared subject's drawing. Next the deviation between the appropriate standard dot and the position of the element characteristic on the subject's drawing was measured using the Macpaint cursor position box. For example, the template containing dots indicating the correct positions of the element-border intersections was pasted onto a copy of the subject's drawing and the cursor zeroed on the centre of one of the standard dots. The cursor was then shifted to the corresponding element-border intersection and the distance between these two positions determined. This process continued until the deviations for all the elements involved in element-border intersections had been recorded.

COMMUNICATING RESULTS

One of the problems in reporting results arising from this type of research is that there are no suitable established forms of display for communicating some aspects of the findings. Particularly problematic is the communication of the subjects' processing activities in a manner that conveys their essentially dynamic character. The results covering the sequence in which markings were added to the blank map involve sets of temporal and spatial information that are difficult to integrate effectively on a single display. Initial attempts to depict the sequence using a series of 34 individual weather map diagrams in a comic strip type format dispersed the information too widely to be useful to someone trying to grasp the overall pattern of results. After a variety of experiments with different approaches to the display of both temporal and spatial information, a format was devised that used a different graphic property to handle each of these different types of information.

The spatial information was depicted in its normal form by markings with the same shape and position as those that made up the display. However, the temporal information that applied to each marking (the mean position of that marking in the subject group's map construction sequence) was incorporated within the marking itself by means of shading density. A photographic exposure (or sunburn) metaphor was employed in which markings that had been produced earlier in the sequence were drawn with a darker line than those produced later in the sequence. Thus the marking added last in the subject's response was drawn with a light grey while the first marking was drawn with solid black. The graduation in shade of the different markings across the map therefore indicated progression through the drawing sequence. The different maps for the meteorologists and non-meteorologists had identical copies of the markings that differed only in the various levels of grey in which they were drawn. These differences in grey level were set in accordance with the typical sequences produced by the different groups of subjects.

Dynamic Presentation of Results

The order in which subjects built up the set of markings on the weather map was taken as an indicator of the way meteorological information was structured in their mental representations. In reporting results of this type, it was considered important to be able to communicate as effectively as possible the way events unfolded over time. Although the static representations described above which used different levels of grey to indicate the passage of time gave an overview of the marking sequence, their scope for presenting more detailed temporal aspects effectively is limited. Patterns in the accumulation of these markings during the course of task performance are most faithfully displayed in a dynamic manner so that their essential temporal character is retained. To this end, typical sequences for building up the weather map by meteorologists and non-meteorologists were transformed into simple dynamic presentations using an animation program and recorded on videotape. Other parts of this research had shown that the series of markings a subject added to the map was chunked into a number of sub-series. Within each sub-series, the individual markings were related in some way. For example, the non-meteorologists typically had chunks that were made up of a set of markings which all followed a similar shape or which all were located in the same general area of the map. In contrast, meteorologists' chunks tended to be connected by some type of meteorological relationship rather than by superficial graphic characteristics of the display.

To emphasise the chunking patterns, in preparing the animation the time intervals between marking chunks were lengthened considerably while the time intervals within those chunks (between individual markings) were shortened. In addition, each type of time interval (between chunk and within chunk) was regularised. The intention of this exaggeration and smoothing operation was to improve the perceptability of the temporal pattern to the uninitiated observer. At the end of each sequence of markings, various graphic and animated summaries of the chunking patterns were presented to give an overview of the temporal pattern and show possible relationships governing the sequences used.

CONCLUSION

The data analysis techniques described above for dealing with the products of the weather map investigations have the virtues of being easy to implement on a relatively inexpensive computer (a low-end Macintosh) and being simple to use. They are also based upon a commonly available program that is one of the lowest-priced pieces of graphics software. However, the procedures have limitations, both in terms of their accuracy and in the range of graphic characteristics they can measure. In addition, the measurement process is very time consuming and has some aspects that are inevitably rather clumsy because the software is not specifically designed for doing this type of analysis (being intended as a 'painting' program for producing rather than analysing pictures). Despite these drawbacks, the techniques provided a very effective set of analytical tools which were able to generate numerical data that could be subjected to further more traditional forms of analysis. The results obtained indicated that the techniques were sufficiently sensitive to identify a number of fundamental differences between the way members of the two subject groups drew the meteorological markings (Lowe, 1991). These differences were interpreted as a reflection of underlying differences in mental representation.

After the investigation of some of these fundamental differences, the focus of this research has now moved to more subtle aspects of the mental representation of these diagrams. In designing new investigations in this area, it is necessary to consider ways to carry out more sophisticated forms of image processing. Recently the author has begun the analysis of similar diagrammatic material using Image Analyst, a purpose-built graphics analysis system. This specialist item is very much more expensive than Macpaint and requires a high-end Macintosh for its operation. However, it does provide a whole new range of measures for the user, as well as an interface that is specifically designed for analysis of graphics rather than 'painting'. This latter feature has the effect of greatly reducing the amount of preparation and manipulation needed to perform each analysis, so saving a large amount of time. It also allows image refinement processes to be carried out that improve the ease with which measurements can be performed. The data generated from the measurements are automatically collected and can be saved in formats suitable for exporting directly to other programs for further types of analysis.

The additional graphic facilities provided by Image Analyst make it possible to consider a much wider range of investigation strategies. The facilities are now being coodinated with computer-based presentation of experimental tasks that have been developed to allow for direct and real-time input of graphic responses. For example, with these new approaches, subjects can show the changes they think will occur in a given meteorological feature over time. The increased amount and complexity of data gathered in such investigations is offset by the power of this analytical tool to carry out the required processing.

REFERENCES

Anzai, Y., & Yokoyama, Y. (1984). Internal models in physics problem solving. Cognition and Instruction, 1, 397-450.

Chi, M.T.H., Glaser, R., & Farr, M.J. (1988). The nature of expertise. Hillsdale, NJ: Erlbaum.

Larkin, J.H., & Simon, H.A. (1987). Why a diagram is (sometimes) worth ten thousand words. Cognitive Science, 11, 65-99.

Loftus G.R., & Mackworth, N.H. (1978). Cognitive determinants of fixation location during picture viewing. Journal of Experimental Psychology: Human Perception and Performance, 4, 565-572.

Lowe, R.K. (1989). Search strategies and inference in the exploration of scientific diagrams. Educational Psychology, 9(1), 27-44.

Lowe, R.K. (1990). Diagram information and its organisation in memory: Exploring the role of skill and experience. Research in Science Education, 20, 191-199.

Lowe, R.K. (1991, August). Scientists' and non-scientists' mental representation of graphic material in technical diagrams. Paper presented at the Fourth European Conference for Research on Learning and Instruction, Turku, Finland.

Mandler, J.M & Johnson, N.S. (1976). Some of the thousand words a picture is worth. Journal of Experimental Psychology: Human Learning and Memory, 2, 529-540.

Mayer, R.E & Gallini, J.K. (1990). When is an illustration worth ten thousand words? Journal of Educational Psychology, 82, 715-726.

Mayer, R.E. (1989). Systematic thinking fostered by illustrations in scientific text. Journal of Educational Psychology, 81, 240-246.

Salomon, G. (1989). Learning from texts and pictures: Reflections on a metalevel. In H. Mandl & J.R. Levin (Eds.), Knowledge acquisition from text and pictures (pp. 73-82). North Holland: Elsevier.

Seevak, J.J. & Moore, P.J. (1990). Effective processing of visual information. Reading, 24(1), 28-36.

Yarbus, A.L. (1967). Eye movements and vision. New York: Plenum Press.

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DEVELOPING NETWORKS OF GRASS-ROOTS SCIENCE CURRICULUM ACTION

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ABSTRACT

This paper describes an ongoing process of participatory curriculum development. It outlines some of the tensions which need to be explored in science curriculum development: debates about the nature of science, of society, of school science content and of learning theories. The process whereby action can arise from this debate is also explored. An example will be outlined of a network of science curriculum action which has developed from the work of a range of science education projects in Natal, South Africa.

CURRICULUM CHANGE

An examination of prevailing approaches

Many curriculum development activities have favoured positivist approaches to curriculum development. These have usually involved external, rational and objective research processes (curriculum development), followed by dissemination / adoption strategies to communicate the new curriculum to teachers or to implant it in schools (curriculum implementation).

'Develop and implement' approaches to change have, unfortunately, proved to be surprisingly weak (Papagiannis, Klees & Bickel 1982; Popkewitz, 1984). Their repeated failure has most often been ascribed to communication weaknesses, insufficient or poor evaluation and a lack of teacher participation (Eisner, 1985). Curriculum projects have thus centred their efforts on trying to improve evaluation research and communication strategies for curriculum dissemination.

This may well have been a waste of effort as many of the key failings of prevailing approaches to curriculum development can be traced to flaws in the underlying assumptions of a deterministic model of change. Figure 1 (adapted from O'Donoghue & McNaught, 1990) outlines the classic RDDA model. We need to examine carefully the assumption that the management of change through external and rational processes of curriculum development is either possible or desirable.

The RDDA model does not fulfil several of the criteria which educational projects in South Africa have used in order to describe their identity. On a sociopolitical level, the hierarchical power structure implicit in a top-down approach ignores the need for people to be involved in determining the parameters of their own existence. Education is such an important part of our society that any democratic renewal must involve consultation with all stake-holders.

Further, if the learner is to be placed at the centre of the education process, there needs to be elements of sensitivity, flexibility and adaptability in curriculum development that are just not found in curriculum development which is removed from action in the classroom. So, whether one reads psychological constructivist literature (e.g. Driver & Erickson, 1983; Gilbert & Watts, 1983) or the literature of liberation and democracy (e.g. Freire, 1985), it becomes clear that we need alternative models for curriculum development.

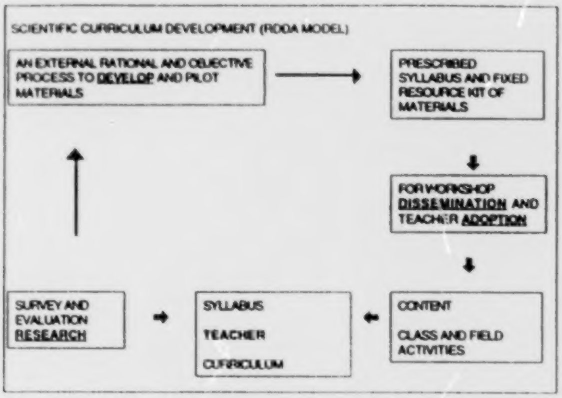
SCIENTIFIC CURRICULUM DEVELOPMENT (RDDA MODEL)
AN EXTERNAL RATIONAL AND OBJECTIVE PROCESS TO DEVELOP AND PILOT MATERIALS
PRESCRIBED SYLLABUS AND FIXED RESOURCE KIT OF MATERIALS
FOR WORKSHOP DISSEMINATION AND TEACHER ADOPTION
CONTENT
CLASS AND FIELD ACTIVITIES
SYLLABUS
TEACHER
CURRICULUM
SURVEY AND EVALUATION RESEARCH

Fig. 1 A deterministic model for curriculum development (RDDA)
(adapted from O'Donoghue & McNaught, 1990)

Developing alternative models

For sustained and meaningful change, people have to reconstruct the way they see the world. This means that groups of people need to become agents of change by reflecting on everyday activities and by acting to resolve the tensions and ambiguities that confront them in their daily lives (Freire & Shor, 1987).

It is important to note that this outlook does not exclude the need for well communicated messages or structured workshops and the provision of resource materials. These do, however, need to arise out of and complement local initiatives. They also need to be undertaken in a way that does not disempower people or inhibit the dialogue and reflection that is necessary for people to reconstruct their own perceptions. We need to approach curriculum development in a way that enables people to take the initiative and to act to become confident thinkers and doers. In this perspective, teachers are partners in the process of change (Taylor & O'Donoghue, 1990).

For some time people in science Inset (inservice education of teachers) projects in South Africa have been aware of the constraints of a deterministic model of curriculum development and, indeed, have realized that the current situation locked them into perpetuating the unsatisfactory status quo. In this situation democratic aims for teacher development become reduced to mere rhetoric. The process of dialogue and reflection about how to democratically facilitate teacher development and curriculum development in science education in South Africa led to SCISA.

WHAT IS SCISA?

The Science Curriculum Initiative in South Africa (SCISA) represents a group of individuals whose concern about the current status of science education in South Africa have motivated them to set about finding a solution. SCISA aims to tackle one of the fundamental needs of science education in our schools, namely the need for all pupils to be introduced to science in primary and lower secondary schools in an exciting, environmentally relevant and conceptually sound way. To this end, we need new science syllabuses and new complementary strategies for science teacher education and professional development.

It is crucial that the production of more relevant syllabuses be linked to the professional development of teachers. The current process of syllabus revision does not permit this and effective curriculum development in a new South Africa must recognize the need to produce other working models for curriculum change.

It is also crucial that all stake-holders in education enter the debate about the nature of science education in our schools. One particularly important group that has been largely excluded from syllabus construction in the past is employers. Commerce and industry are clearly concerned about the shortage of people entering the job market with scientific and mathematical skills. The philosophy of curriculum development which is described in this paper is one where all those concerned with science education in this country need to contribute their views and expertise to a network of ideas and resources. This is ambitious, but possible.

Aims of SCISA

* To develop General Science curricula which are appropriate to the needs of a non-racial society for the whole of South Africa.
* To broaden the base of curriculum decision-making in South Africa.
* To link the professional development of science teachers to the process of curriculum development.
* To liaise with curriculum accrediting bodies.

Anticipated products arising from SCISA

* A new strategy for decision-making about curriculum issues.
* Ongoing workshops as part of teacher support services.
* Strengthened teacher networks for professional development of science teachers. These networks will be both formal and informal.
* A series of stimulus papers and newsletters about science curriculum issues.
* New General Science syllabus documents.
* Exemplar curriculum modules.

The formation of SCISA

SCISA was established as a formal project after a meeting of the Science Forum in Natal in July 1988. Science Forum represents science education projects and departments of education in KwaZulu / Natal. The purpose of the first SCISA workshop was to draft a document highlighting concerns about the current General Science syllabuses. In doing so the group considered philosophical issues about the nature of science, modern learning theories, and articulated the curriculum relevance of environmental and technological concerns. Three basic principles were formulated:

- Scientific ideas are provisional and relative.
- Pupils construct scientific knowledge themselves.
- Environmental (including technological) concerns are central to curriculum development. (McNaught, Raubenheimer & Keogh, 1989, p 3)

These considerations were applied to issues of syllabus design, and the selection of appropriate content and methodologies. The dichotomies shown in Table 1 illustrate the nature of the paradigm shift that was discussed at this first workshop. A stimulus paper was produced and widely disseminated. However, the articulation of issues in the SCISA stimulus document is not sufficient in itself. A process of networking and teacher participation is needed in order to translate these concerns into effective action.

TABLE 1
TENSIONS IN THE CURRICULUM DEBATE (McNaught et al., 1989, p 3)

PHILOSOPHY OF SCIENCE

Current	New
• Science is about facts.	• Scientific theories are provisional and relative.
• Objective, apolitical and value free.	• Socially constructed.
• The way of describing reality.	• One way of understanding our environment.

SOCIETY

Current	New
Academics set the curriculum.	• Community involvement.
• Certification.	• Quality of education.
• Competition.	• Cooperation.
• Schools isolated from the community.	• Workplace input into education.

CHILDREN'S LEARNING

Current	New
• Child as the receiver of knowledge.	• Child constructs meaning with teacher support.
• Children are empty vessels.	• Children bring their own conceptions.
Uniform approach.	• Variety essential.

CONTENT

Current	New
Facts dominate the syllabus.	• Skills and processes must dominate.
Syllabuses are long.	• Syllabuses must be shorter.
Fragmented.	• Integrated.
Academic approach.	• Environmental approach.

Translating the stimulus paper into action
From the beginning of 1989 to mid-1991, about 70 curriculum planning activities (workshops and conference presentations) were run under the auspices of SCISA or the science education projects associated with supporting teacher development and the examination of curriculum issues at primary and lower secondary level.

Many of these workshops began with a discussion of the basic SCISA principles outlined above and some of the ideas contained in the stimulus paper. These ideas were applied to a specific task and a tangible product resulted. This was usually in the form of a poster about the design of a particular teaching module, often in flow diagram form. Teachers contributed a large number of valuable curriculum ideas and these ideas can be readily shared and developed by groups of teachers together. Reports have been produced about each workshop and a source of curriculum ideas is thus rapidly accumulating. What is perhaps even more important, at this stage, is the fact that now many more teachers believe that they have the right to be involved in curriculum planning and appropriate ideas and skills to contribute to the curriculum process. From the beginning the importance of SCISA as a mechanism for teacher empowerment became a central focus.

AN EXPANDING NETWORK

Share-net is an organization that developed at the same time, but separately to SCISA. It developed through the experiences of the staff of the Wildlife Society and the Natal Parks Board who have been supporting teachers for many years by developing resource materials in environmental education. Their first approach was to provide teachers with fully developed and tested materials, but these have either overwhelmed them or disempowered them in other ways. For the past few years an alternative approach has been researched which involves offering teachers and curriculum projects advice and whatever support they think they need for their own environmental education endeavours.

Many of the curriculum ideas which have emerged from SCISA workshops and Share-net projects have been used to generate useful resource materials. Various authors and artists are helping to create resource materials through a participatory process with teachers and a range of materials is now available (e.g. Hart, 1990; Keogh, 1991; Taylor, 1990; Mhlongo & Vilikazi, 1990; O'Donoghue et al., 1989; Umgeni Valley Project, 1989; Urban Foundation, 1990). Many of these materials have been reworked and reissued as reflective action proceeds.

By mid-1990 the central issue for both Share-net and SCISA was that a large number of small projects and several publications existed. The need for a more formal network became increasingly clear so that people could be in touch with one another's work. Also, there is a need for focussing and avoiding duplication so that maximum support can be given to any worthwhile initiative. Other initiatives were also adopting the models being used by SCISA; examples are the Primary Education Forum which was formed to focus on language issues in primary science education and the Inset Policy Iniatiative which aims to support and clarify general Inset principles in South Africa.

It is important to note that the work of SCISA and associated projects has developed in a simultaneous and complementary style. This is not surprising given the extensive and conscious emphasis given to dialogue aimed at critical reflection by the science education network in the Natal region. The expanding network of curriculum development actors in Natal includes the universities, departments of education, teachers, publishers, the Science Forum and industry, also this curriculum network has been strengthened enormously by the breaking down of barriers between initiatives. A concept of curriculum development based on effective participation between all stake-holders in the process is not congruent with the building of educational empires. The cooperative networking of all science projects is essential if dynamic, adaptable science syllabuses and supporting resources are to become a reality in South Africa. This is illustrated in Figure 2. The action research model here is enabling teachers to develop professional skills as well as gaining some measure of professional control. In the South African context this is especially important (Davidoff & Van den Berg, 1990).

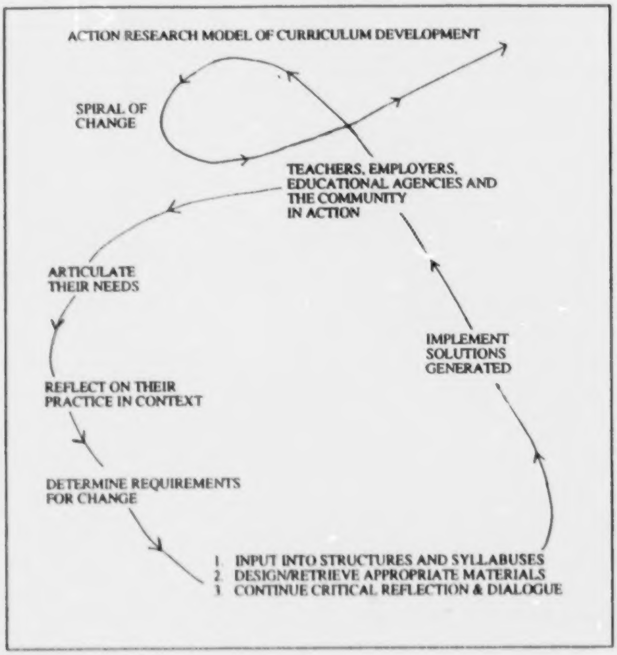
ACTION RESEARCH MODEL OF CURRICULUM DEVELOPMENT
SPIRAL OF CHANGE
TEACHERS, EMPLOYERS, EDUCATIONAL AGENCIES AND THE COMMUNITY IN ACTION
ARTICULATE THEIR NEEDS
REFLECT ON THEIR PRACTICE IN CONTEXT
DETERMINE REQUIREMENTS FOR CHANGE
1. INPUT INTO STRUCTURES AND SYLLABUSES
2. DESIGN/RETRIEVE APPROPRIATE MATERIALS
3. CONTINUE CRITICAL REFLECTION & DIALOGUE
IMPLEMENT SOLUTIONS GENERATED

Fig. 2 A people-centred partnership of curriculum change by reflection and action

SCISA in 1991

By the beginning of 1991, SCISA had become identified as a project which had brought greater coherence to the network of science curriculum action which is continually developing in South Africa. By this stage in the project a great deal of debate was taking place around the issue of which 'domains' SCISA operates within. Taylor et al. (1989) describe the three domains which are central to curriculum as the academic, the bureaucratic and the school. These are obviously influenced by the formal political domain. Emerging curriculum models for South Africa need also to consider the domain of alternative education domain. This concept of mapping domains of concern is a valuable way to explore the balance of a network. For example, the ideas that have been articulated through SCISA have been presented to the official General Science syllabus committee, to the Independent Examining Board (described by The Alternative Education Projects Team, 1989), and to the NECC research project, NEPI (National Education Policy Investigation - linked to the ANC). The decision to attempt to engage with as many domains as possible seems important if a representative science curriculum network is to emerge. This means that constantly SCISA needs to address and debate questions of balance and power relations.

This paper then sets out the context of SCISA's early development. The project is now entering a new phase in which the following activities are being developed.

- The continuation of workshops with teachers to generate curriculum ideas and materials. The products of these working groups could be core curriculum details, exemplar modules and some optional material.
- Networking nationally with educational decision makers within teacher organizations, educational institutions and departments of education to inform and set up debate.
- The production of a newsletter as a forum for science curriculum innovation.
- Liaison with a broad spectrum of organizations with a specific interest in education. This will include community organizations as well as commerce and industry.

REFERENCES

Davidoff, S., & Van den Berg, O. (1990) Changing your teaching. Pietermaritzburg: Centaur Publications.

Driver, R., & Erickson, G. (1983). Theories-in-action: Some theoretical and empirical issues in the studies of students' conceptual frameworks in science. Studies in Science Education, 10, 37 - 60.

Eisner, E. (1985). The educational imagination. New York: Macmillan.

Freire, P. (1985). The politics of education. Hampshire and London: Macmillan.

Freire, P., & Shor, I. (1987). A pedagogy for liberation: Dialogues on transforming education. London: Macmillan.

Gilbert, J. K., & Watts, D. M. (1983). Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. Studies in Science Education, 10, 61 - 98.

Hart, S. (1990). A tale of our tree world. White River: Eco-link, & Howick: Share-Net.

Keogh, M. (1991). Basic science in polyester production. Hammarsdale: South African Nylon Spinners.

McNaught, C., Raubenheimer, D., & Keogh, M (eds) (1989). A General Science syllabus: Standards 3 to 7. Report of a workshop held at Michaelhouse, Natal on 11 - 12 January. Natal: Science Curriculum Initiative in South Africa.

Mhlongo, N. & Vilikazi, R. (1990). Teaching electricity at standard four. Durban: The Urban Foundation.

O'Donoghue, R., & McNaught, C. Environmental education curriculum development: Towards a revised framework of 'grass roots' reconstructive action. In J. van Trommel (ed) Proceedings of an International Symposium on Fieldwork in the

Sciences, Westerbork, The Netherlands, April 1990. Enschede: Institute of Curriculum Development.

O'Donoghue, R., Ngcobo, H., & Van den Berg, I. (1989). Some common soil organisms. Howick: Share-Net.

Papagiannis, G. J., Klees, S. J., & Bickel, R. N. (1982). Towards a political economy of educational innovation. Review of Educational Research, 52, 245 - 290.

Popkewitz, T. S. (1984). Paradigm and ideology in education research. London: Falmer Press.

Taylor, J., & O'Donoghue, R. (1990). Towards a cooperative framework for environmental education. Environmental Education Bulletin, 2, 2 - 5.

Taylor, L. (1990). Some common grasses and grassland organisms. Howick: Share-Net .

Taylor, N., Muller, J., Cloete, N., & Narsing, Y. (1989). The first and last interpreters. Paper presented to the Kenton Conference, Magoesbaskloof, 27 - 30 October.

The Alternative Education Institutions Projects Team - EPU, University of the Witwatersrand. (1989). The Independent Examinations Board: Progress and prospects. Perspectives, 11, 65 - 71.

Umgeni Valley Project. (1989). Some common water organisms. Howick: Share- Net.

Urban Foundation. (1990). Eco-puzzles. Howick: Share-net. (There are 7 puzzles in the series.)

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CONSTRUCTIVISM AND EMPIRICISM: AN INCOMPLETE DIVORCE

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ABSTRACT

The paper outlines the significant influence of constructivism in contemporary science and mathematics education, and emphasises the central role that epistemology plays in constructivist theory and practice. It is claimed that despite the anti-empiricism of much constructivist writing, in most forms its epistemology is nevertheless firmly empiricist. In particular it is subject-centered and experience-based. It is argued that its relativist, if not skeptical conclusions, only follow given these empiricist assumptions. Further it is suggested that such assumptions belong to Aristotelian science, and were effectively overthrown with the modern science of Galileo and Newton. Thus constructivism cannot provide understanding of post-Aristotelian science.

INTRODUCTION

Constructivism is one of the major influences in present day science and mathematics education. Perhaps with only slight exaggeration one participant at the 1991 US National Association for Research in Science Teaching annual conference announced 'now we are all constructivists'.

There is much that is laudable, insightful, and progressive about constructivist theory and practice. It is far superior to the mindless behaviourist theory of mind and learning against which Piaget, and early cognitive psychologists such as Bruner, struggled. Constructivism's stress on pupil engagement in learning, and the importance of understanding student's current conceptual schemes in order to teach fruitfully, are progressive; as is its stress on dialogue, conversation, argument, and the justification of student and teacher opinions in a social setting. Importantly constructivism's stress on understanding as the goal of science instruction is a major advance over the rote learning and mantra-like repetition of formulae that characterises so many science classrooms - classrooms like the graduate class of which Richard Feynman said 'the students had memorised everything, but they didn't know what anything meant' (Feynman, 1985, p.212).

Given the enormous influence of constructivism, it is timely that its philosophical underpinnings be examined. This paper will contribute to such examination by trying to identify the degree to which much constructivist epistemology remains firmly, and I believe fatally, in the grip of empiricist views of knowledge development and validation. If this empiricist shadow were to be removed from constructivism then a good deal of its curriculum theorising would be different, and a good deal of its pedagogy would also be different.

Constructivism sets out to separate itself from positivism and empiricism, yet the separation is far from complete, and the divorce utlimately does not proceed. Or to change metaphors, the situation is something like the person who renounces Christian belief, but has so absorbed Christian doctrine that, atheistic though they may be, they still interpret and act in the world in religious ways.

PHILOSOPHICAL BACKGROUND AND COMMITMENTS

Constructivism, at least as it appears in science and mathematics education, has been contributed to by a number of significant intellectual movements: the genetic epistemology of Piaget, post-positivist philosophy of science, Edinburgh School sociology of science, Kelly's personal construct psychology, Vygotskian theory of language acquisition.

Constructivism in science and mathematics education is not just a theory of human concept formation and learning, nor just a theory of the way science develops and is validated; it is perhaps pre-eminately a theory of education (to use the title of one prominent constructivist's book - Novak, 1977). It is a view about how teaching should proceed, how children should be treated, how classrooms should be organised, how curricula should be developed and implemented, and sometimes even a view about the purposes of schooling.

Thus it is not suprising that constructivism fairly bristles with philosophical commitments. It explicitly assumes and champions positions in the philosophy of science, the philosophy of mind, and the philosophy of education. It is at once a theory of science, of human learning, and of teaching. The range of constructivist concerns can be seen in the following sub-headings contained in a recent science education article: 'A Constructivist View of Learning', 'A Constructivist View of Teaching', 'A View of Science', 'Aims of Science Education', 'A Constructivist View of Curriculum', 'A Constructivist View of Curriculum Development' (Bell, 1991).

In this paper I wish to concentrate upon the epistemological commitments of constructivism. Some extracts from constructivist writings can give a sense of the pervasiveness of these commitments:

> such [constructivist] approaches view knowledge as personally and socially constructed, rather than 'objective' and revealed; theories as provisional, not absolute. (Millar & Driver, 1987, p.57)

> Put into simple terms, constructivism can be described as essentially a theory about the limits of human knowledge, a belief that all knowledge is necessarily a product of our own cognitive acts. We can have no direct or unmediated knowledge of any external or objective reality. We construct our understanding through our experiences, and the character of our experience is influenced profoundly by our cognitive lens. (Confrey 1990, p.108)

> Scientific knowledge is invented in order to make sense of observations which are themselves theory-laden. There is no great book of nature that can be consulted in order to check if the models or theories correspond to an ontological reality.(Desautels & Larochelle, 1990, p.236)

> Constructivism is, logically, a post-epistemological position. The standard questions of epistemology cannot be answered - or even reasonably asked - from this perspective. Its premises suggest, rather, abandonment of traditional epistemological language. (Noddings, 1990, p.18)

However epistemology, even when abandoned, is important to constructivism, indeed I believe it drives the rest of constructivist educational theory and practice.

Although there are variations in constructivist epistemology, the common thread is that it is individual-centred, experience-based, and relativist. But its relativism needs to be distinguished from other relativisms in which the goal of science as a search for truth about the world is accepted, and it is then asserted that we cannot know of different accounts which one is actually true or better. In contrast for most constructivists our knowledge does not tell us about the world at all, it tells us about our experiences, and how they are best organised.

Lerman (1989), following Kilpatrick (1987), suggests that the core epistemological theses of constructivism are:

> (1) Knowledge is actively constructed by the cognizing subject, not passively received from the environment.
> (2) Coming to know is an adaptive process that organizes one's experiential world; it does not discover an independent, pre-existing world outside the mind of the knower.

The first thesis (1) is a psychological claim, the second (2) is an epistemological claim. Lerman believes (1) implies (2).

CONSTRUCTIVISM AS A FORM OF EMPIRICISM

My criticism of constructivist epistemology is, in brief, that constructivism maintains the Aristotelian-empiricist epistemological paradigm, and by correctly pointing to a major error in empiricist assumptions, it then swings to a relativist epistemology without abandoning the paradigm itself. The relativist conclusion only follows within the empiricist paradigm, if this paradigm is rejected, no such relativist epistemological conclusions follow, and certainly no idealist ontological conclusions follow.

To understand my argument it is necessary to allude to the Aristotelian conception of knowledge which in one guise or another has so dominated the history of epistemological reflection.

Aristotle assumed a world independent of people populated by individual substances that formed classes or species in virtue of their essences or forms. To know something was to know its essence, or nature. Knowers were in two important senses passive in the Aristotelian theory of knowledge: first, the world imprinted empirical knowledge on the subject through ordinary unmediated sense-perception - this had to be unmediated in order for the object of knowledge to be known as it actually was; second, the knower could not interfere with what he or she was hoping to know. Aristotle held a non-interference epistemological policy. Once the ideal epistemological stand-off was achieved - where the knower did not interfere with the known - then the rational faculty (nous) of the knower by a process of induction (epagoge) intuited the universal forms inherent in the known.

As Dewey and Popper have observed, Aristotle basically held an empiricist, individualistic, reflective or correspondence theory of knowledge (the 'Spectator' theory) : knowledge was something generated by, and residing inside, an observer. To the extent that the world or object was interfered with then knowledge was thwarted. To the extent that the subject was active in knowledge acquisition, then knowledge was compromised. Thus there was no experimental tradition in Aristotelian science, it was a tradition of observing nature in its natural state, a tradition that placed great empahasis on the eye, not the hand.

Observation, vision, and looking, were the key elements in the subject side of Aristotle's epistemological equation, on the other object side the key element was undisturbed nature. Knowledge was obtained when the subject side accurately mirrored the object side. Aristotle's epistemological dictum was: 'to say of what is that it is, and of what is not that it is not, is true'. With the Scholastics this became the doctrine that truth is the adequation (or correspondence) of things and the intellect.

Despite their anti-Aristotelian rhetoric, the British empiricists of the seventeenth century - Bacon, Locke, Berkeley, and Hume - maintained in all essentials this Aristotelian paradigm of knowledge. Knowledge was an individual matter, it was grounded in experience or sense impressions, its criterion was adequacy between thought and reality or the correspondence of ideas with objects.

Any epistemology which formulates the problem of knowledge in terms of a subject looking at an object and asking how well what is seen reflects the nature or essence of the object is quintessentially Aristotelian or, more generally, empiricist. Aristotelians were direct realists about perception, that is the objects of perception were material bodies, what we looked at were bodies in the world; later empiricists, Locke, Hume and Berkeley, were largely indirect realists, that is the objects of perception were sense impressions generated, it was supposed, by material objects.

Variations of this classical empiricist account of the origin of ideas recurr in contemporary constructivist writings. Consider Osborne and Wittrock's influential 1985 generative learning model. There they say (p.64-65) that the key postulates of the model include:

- The learner's existing ideas influence what use is made of the senses and in this way the brain can be said to actively select sensory input.
- Learner's existing ideas will influence what sensory input is attended to and what is ignored.
- The input selected or attended to by the learner, of itself, has no inherent meaning.

And they proceed to discuss constructivist teaching in terms of 'sensory input' provided by the teacher. They acknowledge that the construction or generation of complex meanings is not straight-forward, this has to be done by the students 'producing their own sensory inputs' - tables, diagrams, flow charts etc. It is claimed that the science classroom is a particularly appropriate site for testing the generative learning model because:

> The sensory input can be clearly specified (e.g. reading a scientific text), or consist of a full range of sensory input (e.g. the science laboratory experiment), depending on the nature of the particular research study. (p.80)

Within this paradigm, framework, or problematic, the possibility of knowledge weakened once it was pointed out that the mind is active in cognition, not just in intuiting the forms, but in structuring the experiences that the senses provide; and the possibility of knowledge of an external world evaporated once it was claimed that the immediate objects of the intellectual faculty were sense impressions rather than nature itself. Nature, or in Kant's terms, the thing-in-itself, became unknowable, because we only ever see it through a distorting lens and there is no priviliged position from which to check the adequacy, or correspondence, of thought to reality. Whether subjects are seeing through a lens clearly or darkly, it is the metaphor of seeing through a lens which signals commitment to an empiricist theory of knowledge.

The one-step argument from the psychological premiss 'the mind is active in knowledge acquisition' to the epistemological conclusion 'we cannot know reality' is endemic in constructivist writing. Lerman speaks for many when he says of the two theses - (1) and (2) above - that 'the connections between hypothesis (1) and (2) seem to be quite strong' (1989, p.212).

But this conclusion only follows on the assumption that Aristotle had in fact correctly delineated the problem of knowledge; the conclusion only follows if the terms of the problem as stated by Aristotle are accepted. If this assumption is rejected then none of the skeptical conclusions of constructivism follow.

THE SCIENTIFIC-EPISTEMOLOGICAL REVOLUTION

Although presented here in a condensed and largely suggestive manner, I will use the example of the scientific and epistemological revolution of the seventeenth century to illustrate the limitations of empiricism generally, and constructivism specifically, in grasping, let alone solving, the epistemological problem presented by modern science. The example also allows some of the powerful but partial insights of constructivism to be demonstrated.

Galileo's account of pendulum motion well illustrates the difference between the theoretical objects of Galileo's science and the real objects in the world. (On this matter see Matthews, 1987, 1990.)

Galilean science applied to a highly constrained experimental situation formed only on the design provided by the theoretical object. The real was altered, that is refined and perfected, to correspond with the theoretical, not the other way around as del Monte the Aristotelian, and more generally empiricists would insist in their claim that theory should be brought into line with reality. That the theoretical object did not correspond with the real was beside the point. Subsequently an interplay of theory - abandoning for instance Galileo's view that the circle was the brachistochrone, or curve of quickest descent - and experimental refinement lead to Huyghen's improvement of the law of pendulum motion.

Seeing or observing things differently was just not important in the debate between Galileo and del Monte. Galileo did not see point masses at the end of weightless strings, nor did he see continuous motion at the zenith of swing, he saw exactly what del Monte saw - chandeliers on the end of chains, lead balls on the end of wire, pendulums which momentarily stopped at their zenith, and pendulums which came to a halt within about two-dozen oscillations etc. Observation - whether theory dependent or not - was barely relevant to the dispute. Galileo described things differently, he did not see things differently. The new descriptions did not come from looking - after all one of the greatest observers of all time, Leonardo da Vinci, had long looked at pendulums without describing them in the way Galileo did - the descriptions came from an intellectually constructed theoretical object. Once described mathematically these statements were able to be worked upon by his mechanical system.

As one commentator has said: 'observation and experience, in the sense of brute, commonsense experience, did not play a major role - or if it did, it was a negative one, the role of obstacle, in the foundation of modern science' (Koyre, 1968, p.18).

CONSTRUCTIVE CRITICISM

Constructivism is correct in stressing the inventive, humane, culturally and temporally dependent aspects of creating the theoretical objects of science - but none of this bears, of itself, upon truth. Further, although constructivists stress this creative aspect of knowledge production, they seldom extend the analysis: their model of creation is a sort of personal, cottage-industry, model. It is the personal, Robinson Crusoe, model of knowledge construction that leaves aside the necessary social and communitarian dimensions of cognition - the dimensions that inclined Freire, following Hegel, to say that 'it is the "we think" that determines the "I think" and not the other way around'.

Wheatley (1991) is partially correct when he says that the objects of science do not just lie around. Where he and most constructivists, in company with Aristotle and the empiricists, go wrong is in failing to distinguish the theoretical objects of science, which do not lie around, from the real objects of science, which do lie around and fall on people's heads.

Importantly even the theoretical objects, once produced, have a reality even if they are not exactly lying around. Newton's mechanics, Darwin's evolutionary theory, and Mendel's genetics all exist and can be apprehended by, and taught to, subsequent thinkers - it is just that they are not to be confused with falling apples, grazing animals, or fields of peas.

Recently Louis Althusser and Karl Popper have well expressed the objectivist theory of knowledge that can be counterposed to personal constructivism. The latter has said:

> My ... thesis involves the existence of two different senses of knowledge or of thought: (1) knowledge or thought in the subjective sense, consisting of a state of mind or consciousness or a disposition to behave or act, and (2) knowledge or thought in an objective sense, consisting of problems, theories, and

> arguments as such. Knowledge in this objective sense is totally independent of anybody's claim to know; it is also independent of anybody's belief, or disposition to assent; or to assert or to act. (Popper, 1972, p.108)

Empiricism, and constructivism, conceives the enterprise of science in terms of individuals looking at the world and trying to ascertain whether their ideas, concepts, and conceptualisations make sense. In the words of the New Zealand Draft 1-5 Syllabus: 'Science is about people exploring and investigating their biological, physical, and technological worlds, and making sense of them in logical and creative ways' (Bell, 1990, p.5).

Objectivist epistemology distinguishes between the raw material and events of the world (the real objects of science), the theoretical structures and concepts of science, the material and events as described by the theory (the theoretical objects of science), and the experimental and technical procedures of science. Individual understanding and conceptualisation is parasitic upon this extra-individual scientific domain. Science education can then be conceived in terms of the appropriate introduction of individuals into this world of concepts, understandings, techniques and community standards.

Constructivists, as with turn-of-the-century positivists such as Mach, Poincare, and Duhem, once they roll back our knowledge to knowledge of sensory input, are then inexorably led to speak of the aims of science as being the 'making sense of our world', or for the more consistent, 'making sense of our sense impressions'. Alternatively this view leads to a purely instrumentalist interpretation of scientific theory. Both alternatives are in contrast to realism where the aim of science is the understanding or explanation of our world. Science may not achieve the aim, but there is agreement that science is the attempt to comprehend something outside ourselves.

Once this positivist limitation on scientific knowledge is accepted, then constructivist recommendations for the science curriculum inexorably move to formulations such as students should 'make sense of the world around them', or 'make sense of the living world'. This talk of 'making sense' is quintessentially empiricist. It is also fraught with grave educational and cultural implications. It leads immediately, as it has historically done, to relativisms of all kind.

It is notorious that people have for centuries thought that the grossest injustices, and the greatest evils, have all made sense. Likewise most scientific advances have entailed commitment to propositions that did not only defy sense - Galileo's point masses and colourless bodies, Newton's inertial systems, Darwin's gradualist evolutionary assumptions, Einstein's mass-energy equivalence etc - but also defied accepted scientific, social, cultural, or religious norms. 'Making sense' of our sensory inputs hardly seems sufficient warrant to maintain the scientific enterprise; and in a science classroom it hardly seems sufficient warrant for the teacher to disturb deeply ingrained and important beliefs of children. Finding out the truth might provide such warrant.

And if, as some constructivists say, we merely start with what makes sense to students, and then proceed to encourage them along to the current scientific view, despite intermediate false views seeming to make sense to them, then the question arises as to why do we do this? What is it that we think is important about science that warrants this interference with ingrained and comfortable belief? It can only be that science makes more sense. But the reason it makes more sense cannot be spelt out in terms of sensory inputs. This whole formulation of the issue is simply mistaken.

Von Glasersfeld says often that the orthodox epistemological problem has to be abandoned, and that correspondence as a mark of truth needs to be rejected. This is because on his terms we cannot see reality, we only have our sensations to reflect upon, and so we are never able to judge correspondence between our ideas and the world (a restatement of Berkeley's argument). He sometimes replaces correspondence with pragmatism, and in other places with coherence among experience. My suggestion is that this is a case of old Aristotelian wine in a new constructivist bottle. This leads him, and Nel Noddings for instance, to speak of constructivism as being post-epistemological. His original subject-observing-an-object formulation does lead to an impasse, and one appreciates why he wants to abandon epistemology. But the mistake is to give up wine drinking because all the contents of one vintage are undrinkable; there are other vintages which allow epistemological imbibing to proceed with interest, enjoyment and profit.

REFERENCES

Bell, B. (1990). Draft forms 1-5 science syllabus. Wellington: Ministry of Education.

Bell, B. (1991). A constructivist view of learning and the draft forms 1-5 science syllabus. SAME Papers, Hamilton: University of Waikato.

Confrey, J. (1990). What constructivism implies for teaching. In R.B. Davis, C.A. Maher, & N. Noddings (eds.) Constructivist views on the teaching and learning of mathematics. Reston, VA: National Council of Teachers of Mathematics, pp.107-122.

Desautels, J. & Larochelle, M. (1990). A constructivist pedagogical strategy: the epistemological disturbance (experiment and preliminary results). In D.E. Herget (ed.) More history and philosophy of science in science teaching. Tallahassee, Fl: Florida State University.

Feynman, R. (1985). Surely you're joking Mr Feynman. New York: Bantam Books.

Glasersfeld, E. von (1989). Cognition, construction of knowledge, and teaching. Synthese, 80(1), 121-140.

Kilpatrick, J. (1987). What constructivism might be in mathematics education. In J.C. Bergeron, N. Herscovics, & C. Keiran (eds.) Psychology of mathematics education. Montreal: Proceedings of the Eleventh International Conference, pp. 3-27.

Koyre, A. (1968). Metaphysics and measurement. Cambridge MA: Harvard University Press.

Lerman, S. (1989). Constructivism, mathematics, and mathematics education. Educational Studies in Mathematics, 20, 211-223.

Matthews, M.R. (1987). Galileo's pendulum and the objects of science. Philosophy of Education, pp. 309-319.

Matthews, M.R. (1990). Galileo and pendulum motion: a case for history and philosophy in the science classroom. The Australian Science Teachers Journal, 36 (1), 7-13.

Millar, R. & Driver, R. (1987). Beyond processes. Studies in Science Education, 14, 33-62.

Noddings, N. (1990). Constructivism in mathematics education. In R.B. Davis, C.A. Maher, & N. Noddings (eds.) Constructivist views on the teaching and learning of mathematics. Reston, VA: National Council of Teachers of Mathematics, pp.7-18.

Novak, J. (1977). A theory of education. Cornell: Cornell University Press.

Osborne, R.J. & Wittrock, M.C. (1985). The generative learning model and its implications for science education. Studies in Science Education, 12, 59-87.

Popper, K.R. (1972). Objective knowledge: an evolutionary approach. Oxford: Oxford University Press.

Suchting, W.A. (1992). Constructivism deconstructed. Science and Education, 1 (3).

Wheatley, G.H. (1991). Constructivist perspectives on science and mathematics learning. Science Education, 75 (1), 9-22.

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CAN ANY GOOD COME OUT OF RESEARCHING IN SCIENCE EDUCATION AND BEING A SCIENCE TEACHER AT THE SAME TIME?

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ABSTRACT

Recent experience has demonstrated that for an aged researcher, teaching secondary school science at a selective high school while committed to carrying out research in science education is riddled with difficulties. With respect to the research, problems ranged from there being too much time required to establish one's credentials as a teacher, to too much research being too easily suggested and undertaken. With respect to the teaching, among other things, it was too time-consuming, there were too many other duties to perform and other teachers became too involved in one's own interests. To make matters worse, there were too many students, they were too varied, too interesting and the relationship with them became too rewarding. A thoroughly disturbing state of affairs.

INTRODUCTION

Both teacher educators and education researchers are under some pressure to visit if not re-visit the classroom from time to time. Research and teacher education that is not informed by practice is likely to be misdirected if not misinformed.

Recently I decided to take six months study leave for the purpose of carrying out research with the location being a secondary school rather than a tertiary institution. Though the school was highly selective on an academic basis, I foolishly mentioned, with only a little fear and trepidation, that I wouldn't mind teaching the odd class or two for the odd lesson or two. As circumstances developed, I ended up teaching 15 to 18 periods a week for one term and somewhat more for half of a second term. I became a member of staff, though with a reduced load. I also acquired extra-curricular responsibilities. In short, I became a science teacher. At the same time I embarked on several research projects. It was a mistake and for a number of reasons. Problems arose with respect to the research, the teaching and the pupils themselves. What follows are reflections on personal recollections, but never made with tongue in cheek.

THE RESEARCH

Credibility

Teachers seemed to think that unless I could prove myself as a teacher, any research I chose to undertake with any of their pupils probably wouldn't be worth much. I offered to carry out any investigation teachers thought worth doing, while giving them a few suggestions as to what such investigations might be. Initially teachers were a little slow to make a response. Even if it were at all possible, establishing credibility was going to take some time, somewhere between six weeks and a year. Why would teachers be suspicious of the research we do?

Research ideas

Meanwhile, having begun to teach, ideas for research involving my own classes immediately began to suggest themselves. I had just started to teach a unit on Light to year 7 students (having mistakingly prepared a unit on Energy!). What did they really believe about light, reflection, absorption and refraction? What did they believe and why, with respect to coloured filters, coloured paper and images being back to front but right way up? I must confess my basic interest was with student's understandings and a few other areas, such as inherent problems in practical exercises. Imagine the plethora of questions that might have arisen if my research interests had been wide ranging. As narrow as they were, the problem was I still had too many ideas. Furthermore, I had yet to teach a number of classes with different topics to be introduced. At the six weeks stage some of the other science teachers began to have too many ideas as well. Table 1 indicates the research studies I eventually undertook, having severely pulled the reins in on my curiosity.

TABLE 1
RESEARCH STUDIES UNDERTAKEN

Light and Mirrors
Mass, Weight, Solids and Gases
Hot Air Balloons and Flotation
Plants
Chemical Reactions
Tides
Analysis of Years 11 & 12 Practical Exam Responses:
  Nail Falling; Flea Jumping; Trolley Rolling
School Subject Appraisal
Black and White Body Radiation Exercise

Research origins

Some of the ideas were an immediate consequence of my own teaching, some arose as suggestions of or as initiatives taken by other teachers, two had some beginnings in a research article I had read and some arose by my taking the opportunity to examine student responses to practical examination questions teachers had designed. In most instances, the research programs developed within the science staff room with proposals being appraised by one or more teachers. More often than not there search took the form of a lengthy questionnaire, with the intention that this be followed by student interviews. I never got around to the interviews. I am also ashamed to confess that one of the projects I enjoyed most of all was the one on the Black and White Body Radiation Exercise. It was science rather than education. Ultimately, I did it because I enjoyed it!

Research analysis

Beating off many ideas that soon were too easily forthcoming and likely to overwhelm me, I had still generated too many research projects. The data now began to pour in as a flood. I had stacks of it. Again to my shame, to date, too little of it has been analysed. The teachers having become involved and interested, anticipated the immediate acquisition of rich insights into their teaching and students' learning. They were to be bitterly dissapointed. The opportunity for conjecture as to what was going on, what it all meant and how things might change had come, but teaching responsibilities move on relentlessly and so these opportunities were swiftly gone. A pity that we had come to expect too much too soon.

Research worth

Perhaps the research wouldn't be worth all that much. It was too school, class, pupil and problem specific. What value could there be in research dealing with a highly selective boys secondary school in the state of NSW, Australia, with data, on highly specific issues, collected from individuals making up single classes or school years?

THE TEACHING

Of course the research could have been better handled if I hadn't been teaching. It was really a catch 22 situation: less teaching, more limited research; more teaching, lots of research but too little completed. Well, the "more teaching" was to provide me, now from a science teacher educator's point of view, with quite a shock.

Settling in

I arrived at the school one day. I began teaching the next. It would be easy - it was a reduced load and I was a teacher educator. Unfortunately I was to be reminded of many of the things I had passed on to my tertiary students in all my foolishness. One day was nothing like enough to settle in. Simply learning the procedures of ordering equipment, getting the right video channel, photocopying, obtaining food, or receiving and sending mail, meant one walked in a translucent daze.

Too many people

More difficult and significant was the job of relating to the 15 other science teachers, 2 laboratory assistants, and other teachers - acquaintances of old - many whose names I had forgotten, a Headmaster, Bursar, engineer extraordinaire etc. As simple a skill as distinguishing between those who liked to be told a joke from those who only liked to tell them had to be acquired. Worse still, this was a teaching task that I had been given and I had to relate to students, many of them and all different and half the time I can't even remember names. Table 2 lists the classes and subjects that I taught.

TABLE 2
CLASSES & SUBJECTS TAUGHT

Year 7 Junior Science:	Light Living Things Heat & Temperature
Year 7 Junior Science:	Fossils Chemical Materials
Year 9 Junior Science:	Food, Diet & Wellbeing I
Year 10 Junior Science:	Wellbeing II
Year 11 Biology:	Flowering Plants: Structure & Function
Year 12 Chemistry:	Atoms and Molecules
Year 12 Chemistry:	Organic Chemistry
Year 12 Physics:	Photography

Too little time

There was to be no dilation of time experience for me. Lessons to be prepared, resources got ready, changed, improved and extended. Above all, as a teacher, my mind would not be available for vast blocks of time. As with the taxi sign, a mind "Not for Hire". If I wasn't teaching my class I might be teaching someone else's class. Even when not teaching, I might find myself at a compulsory assembly, at an education committee considering the

International Baccalaureate program, at a science staff meeting, supporting a students' Crusader Union meeting or appreciating a production given by a theatrical group. I was exempt from sports duties (probably being too old). I might find myself marking homework, handing out locker keys to those who had lost them, taking my tutorial class on an outing (but that's another story, told below), setting exam questions, marking exam papers or writing reports. If I was not doing any of these things, I was rushing somewhere in order to be able to do them. I was being reminded that teachers work very hard and have little time to do all that is required. No wonder so very few results were analysed and pondered upon.

Ignorance, ideals and the practical

As one who had not taught science in a secondary school for almost nineteen years, though I had been teaching others to teach science during that time, I discovered there was too much new science to learn! Forget the ideal settings and strategies for teaching, I had to learn some science. Then there were the deadlines, always the deadlines. Even if one were committed to certain teaching strategies, the programs, with their in builttime fuses, brooked no delay and for the most part, no "fancy teaching". As a compromise, one found oneself teaching the way one really wanted to for a short period of time, then having to pack far too much into the time remaining.

I particularly enjoyed play-ground duty and exam supervision.

Disappointingly, though I had set myself the goal of being a different type of teacher than the one I had been so many years before, I found myself too easily reverting to old styles, particularly of management, when the going got tough. Interesting. Another topic for research.

Teachers becoming too interested

To some extent, another bothersome aspect was that too many teachers, in the course of time, became too easy to get along with. After a while a number became interested in the possibility of someone else reflecting on their teaching and suggested that I come along to some of their classes to see what was going on. This was particularly disturbing on those occasions when teachers imagined there might be some benefit in my coming back a second time. I must confess (again) that I was partly to blame, since I had given an open invitation for anyone to have me observe their classes. Once some teachers began to invite me, others, feeling the pressure, felt they had to invite me as well. In each class the teacher concerned and I had to try and make some great discovery. One teacher discovered that it was far easier having two, rather than one, teach his class for their double period and to compound matters, I enjoyed it. Teachers began to discover (or they had known it all along) that discussing what students understood with respect to certain concepts and what we teachers understood with respect to those same concepts was almost as enjoyable as eating or telling jokes. But always for all those who reflected on what might be, there was too much tension between the ideal and the practical.

THE PUPILS

Too many

It is an old saying, but worth repeating: "Teaching wouldn't be too bad except for the pupils". I wanted to carry out the research, I got "trapped" into teaching and I was lumbered with the pupils! There were far too many of them and not one of them was the same. How can a teacher be expected to genuinely care for them as individuals? How can someone interested in research afford to try? I remember sitting in seminar fashion with a group of year 8 students, the top level class (someone else's class I was teaching!), discussing with them what school subjects they really enjoyed and what scientific disciplines within science they enjoyed most. The only thing that one could get a clear majority view on was that they didn't intend to pursue science as a career, though some aspects of science they thought were indeed interesting.

Pupils interfering with the research

Unfortunately, from a research point of view, on some occasions, students displayed a genuine interest in the research of which they were part. How can one expect to produce research data, under such circumstances that is not contaminated with a subject: test second order interaction? Some students thought I was joking when I said I didn't wish to have their names recorded on a questionnaire, unless they wished to have it so recorded. Upon receiving the questionnaire, amazement set in when it was clear that I had spoken the truth. Undoubtedly, the astonishment itself must have affected the results.

Pupils had other interests and needs

Another disappointing feature of my experience was to find that as far as students are concerned, school science only occupies a small fraction of their life, considerable competition coming from other areas. One of my classes was a year 7 science class which I also "taught" as a tutorial group. For this group I was obliged to act as a mother or father figure. Part of my duty to care was met in having picnics, going ten pin bowling, visiting a law court, viewing Robin Hood and eating at McDonald's. Students endeavoured, partly successfully, to persuade me that I owed them certain tutorial periods which I could pay back by substituting them for science lessons. It dawned on me that research in science education was somewhat limited in focus. My view on this matter was particularly reinforced when we visited the law court. While there, we heard a judge pronounce sentence on a drug dealer, at which time one of the students became upset to the point of crying. "I'm not worried about the man, it's his wife I feel sorry for", he managed to say. What an error, to think of engaging in research, being a science teacher and being a counsellor, all at the one time. They have too many interests and too many needs and most outside of science.

Too demanding

The students also asked for too much. Many of them were very high achievers. They treated you as a person who had a duty to guarantee them "good results". A record such as obtaining all top ten places in the Higher School Certificate in the state of NSW in 4 unit science in 1990 didn't help. In 1991, tragedy struck when that tenth place was shared with a student from another school, a female. They wanted the teachers to be experts. What teacher then, has time for research or having students engage in genuine science? One student confronted me with a past examination paper of the school in which a question was asked that allowed for the determination of two different answers to the same question. His query was: "Is the question more difficult than I suppose or is the question corrupt? "Corrupt it was and to be given that advice, for him, was more important than any science involved. Put the research and teaching aside for one moment. In order for any of it to occur, these students needed to be managed or manage themselves. Sometimes the reality was the former. There were management demands ... on me. The time that I lost two scalpels was interesting. Calling upon all my resources of the dramatic and referring to these items as lethal weapons of interest to the police, meant that the scalpels were mysteriously found and by the pupils themselves, within the 24 hour deadline. Another worthy research domain, but not basically of the science education type. Imagine my powers of concentration on science education research matters, during the time when the mystery was unsolved.

Too interesting

Almost of paramount significance, the students, even within science lessons and even while actually on task, were tremendously interesting entities, their behaviour sometime s relegating research to second place. After carefully explaining the workings of a Liebig condensor operating quite successfully in front of us all, one student expressed puzzlement as to why another student was claiming that the water being obtained at the delivery tube end had come from the copper (II) sulfate solution in the distilling flask. Surely it was obvious that water was being delivered by the tap to the condensor and then out to the delivery tube. Forget the research, I had to work harder at teaching. The question was asked by a pupil "Would a man born 4000 years ago look like an ape?" "Let us imagine", I replied, "that a man born 1 000 000 years ago looked just a little bit like an ape ..." I was unable to finish. Suddenly answering his own question he responded, "Of course not, 4 000 is only 0.4% of 1 000 000 and insignificant". He was 12 years old. The best laugh I had in this entire sad tale of my experience was created for me in a class where a teacher asked a group of not too interested year 9 students: "Who could tell us how many moles of carbon dioxide have been lost?" There was some murmuring and then one thoughtful student replied, with perfect timing for each word, "Sir, I believe you could do that".

Too rewarding

Finally, one of the greatest triumphs of schooling over research is to be found in the rewarding relationship that can be established between students and teacher (and between teacher and teachers). I fell seriously ill in the last week of the last term. The head of science, weighed down with research data that sympathetic teachers had collected for me upon their own volition (curse them for compounding some of the problems mentioned above), visited me. However, the choicest item he gave me that day was a card from one of my year 7 classes, each boy having signed his name. Knowing my memory, some had written additional words, identifying themselves thus: "the naughty one", "the talkative one".

CONCLUSION

May this be a warning to you all. With due respect to those few souls who actually teach a few days and then do research for a few days or to those who occasionally teach as part of a specifically designed research program, never carry out science education research and be a science teacher in the ordinary sense at the same time and in the same place. It's a little like savouring the main course and the dessert all in one go.

Alternatively, it or something like it, for all its difficulties has some value and is worth being "given a go". Science education researcher and science educator alike may recall or learn for the first time what schools, teachers, teaching and pupils are really like. With a research mentality, it might just be that such a teacher recognises that ignorance is so great that to reflect and act is to embark upon an exciting adventure into vast uncharted waters. Being a teacher might not only direct research but also inform its findings in ways not anticipated or understood by those who do not teach. The school, its pupils and staff might feel something was achieved, specifically for them, as well as perhaps for others. The researcher, particularly because he/she is both researcher and teacher, might well enjoy it. But you have been warned.

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LEARNING IN PROFESSIONAL PRACTICE SCHOOLS: BEYOND CLINICAL EXPERIENCES AND TEACHER WORKSHOPS

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ABSTRACT

Over the past two years, Florida State University's Science Education Program and Sabal Palm Elementary have collaborated to develop a PPS. The formation of the Sabal Palm PPS was not based upon a predetermined design nor has one group served as an authority to direct how the PPS ought to operate. The success of this model relies on PPS participants working collaboratively to establish goals and plans for actions to be taken to support teacher-learning. The Sabal Palm PPS continues to evolve as dynamic model for creating a center for teacher and student learning. The purpose of this paper is to discuss our involvement in the formation a PPS and implications for enhancing teacher education programs.

INTRODUCTION

To a great extent, teachers and students have had little opportunity to voice their ideas on the matter of changing classroom teaching to promote professionalism in teaching and meaningful student learning (Barth, 1990; Gitlin, 1990; Lortie, 1975). Only recently has educational reform focused on the interactions of those persons most responsible for implementing strategies to improve learning, namely teachers, and those most hopefully to benefit from these endeavous: the students. Efforts have been made to understand the processes involved in teacher-decision making and ways to help teachers become agents of change to enhance teaching and learning practices in schools. Development of Professional Development Schools (PDS) or Professional Practice Schools (PPS) has become a popular endeavour among educational institutions in the United States as a move to improve teacher education programs. There is no clear consensus in research literature regarding why or how a PDS or PPS might be formed. The Holmes Group, one of the leading institutions involved in PDS research, produced a report, Tomorrow's Schools (1990) which defines the PDS as: "...sites of exemplary practice where novice and experienced teachers could be educated and where university and school faculty could collaborate on educational research and development" (p.7). Several themes which have emerged in research literature and which describe guiding principles in developing a PDS/PPS are: dealing with diversity in learning; creating more opportunities for observation and discussion among experienced and prospective teachers and administrators to contributes to the knowledge base of education; fostering understanding and appreciation of different world views; and organising for more equity in education (Holmes Group, 1990; Koerner, 1992; Rushcamp & Roehler, 1992; Winitzky, Stoddart & O'Keefe, 1992).

We have incorporated a number of these ideas in the development of a PPS at Sabal Palm Elementary School. Since 1990, The Science Education Program of Florida State University and Sabal Palm Elementary have collaborated to develop a PPS. Our institutions share a mutual interest to promote professionalism in teaching and to improve classroom learning. The success of this model relies on PPS participants working collaboratively to establish goals and activities to support teacher-learning. Learning is a priority at the Sabal Palm PPS and brings us together as a community striving to promote learning as a meaningful endeavour for all persons.

Constructivism as framework for developing a PPS

Constructivism has served as a framework for developing the Sabal Palm PPS. In simple terms, constructivism proposes that knowledge construction is a process of knowing through personal sense-making. Knowledge is not gained in the objectivist sense as facts to be retrieved from a realm of truths existing somewhere outside of the person; rather, people develop their ideas through a dynamic process of personal sense-making based upon prior experiences and social negotiation of ideas (von Glasersfeld, 1989). As learners socially interact they attempt to communicate their personal understandings, striving to establish consensus of meanings in the group, and to affirm that knowledge constructed is personally viable. Thus, when teacher-learning is framed within a constructivist perspective the emphasis is on how teachers are making sense of teaching through their individual and social interactions.

PPS participants are encouraged learn as reflective practitioners involved in making sense of their actions in light of their beliefs and contextual situations (Schon, 1983). Context in teaching is a key factor influencing teachers' practice as social, cultural and political situations constrain how teachers think and act. Action research is a form of 'collective' self-reflective inquiry by participants of a socio-cultural setting in order to improve, rationalise and justify their practices in that setting. (Kemmis, 1986). We have begun to explore how PPS participants might use action research to enhance teaching and learning in classrooms and the FSU professional teacher education program.

DEVELOPING THE SABAL PALM PPS

Year One : establishing a community of learners among educators

Sabal Palm Elementary is a public school site located in a low socio-economic area approximately 6 km from FSU. In May 1990, four Sabal Palm teachers and the school principal attended a district workshop involving guest speakers from FSU's Science Education Department. The speakers invited teachers to contact them if further interaction was desired. The Sabal Palm group immediately requested the FSU members to present more about constructivism and other ideas which had been shared at the meeting. At the start of the 1990-1991 school year, FSU members presented several staff development workshops at Sabal Palm and found that a group of teachers and the principal wanted to more assistance to reconceptualize their staff development program. A graduate student from FSU volunteered to work with the group and helped them establish opportunities for teachers to interact to share ideas. Action research was introduced as a means of helping the FSU member and the teacher group to identify problems and design strategies to deal with these issues (Dana, 1991). The group established several effective staff development opportunities and requested further collaboration with FSU in the next school year to continue their efforts.

Year 2: creating opportunities for teacher-learning

FSU had become interested in the PPS concept and felt the development of such a model might enhance teacher-learning opportunities for practising and prospective teachers. A meeting was held at Sabal Palm in August, 1991 to propose the idea of developing a PPS with Sabal Palm. Several members from the university and nearly twenty Sabal Palm teachers and the district science supervisor attended the meeting. The university members wanted to avoid the typical approach of "bringing a project" to the school as they felt projects tend to be viewed by school staff as impositions placed upon teachers by outside persons to effect change in schools. In order to promote teacher ownership and leadership the meeting began with brief introductions and a question posed by a university member: "How do you see us working together?" One teacher later reflected on the nature of this discussion:

> Historically, decisions involving changing directions for education -- philosophy, goals, methods, curriculum, standards -- have been made outside the classroom without much teacher input. One important difference between this opportunity for involvement and previous interactions has been the value placed on teacher voice. As the meeting began, Sabal Palm teachers expected administration and university faculty to inform them of their previously designed agenda. Instead, a university member asked, "How do you see us working together?" This teacher empowerment was first met with incredulity and silence. Then, brainstorming tentatively began as classroom teachers realised their ideas really were valued.

It was important that the teachers be the ones to identify their needs for professional development and plan how change should occur. A collaborative PPS model was beginning to emerge as teachers and university members together began to plan ways to enhance their teacher education programs. The teachers and university members proposed several activities for the 1991-1992 school year including: After-school seminars to focus on issues science and mathematics education, participation in restructuring FSU teacher education courses, and continuation of action research. The group wanted one person from each site act to coordinate activities and resources among the two institutions. A kindergarten teacher from Sabal Palm, Betsy, and an FSU graduate student, Sherry, offered to work together to orient each other to their sites. Details such as providing a staff/faculty mail box, explaining schedules and making introductions to key people helped Betsy and Sherry to feel a sense of belonging at the sites. The after-school seminar has become a major link among the two institutions as this time of social interaction helped to build a sense of collegiality and collaboration among participants.

NEW OPPORTUNITIES IN TEACHER EDUCATION

Teachers learning together

The purpose of the PPS seminar group was to provide an opportunity for PPS participants to share their ideas. The PPS seminar group met biweekly after school in the school media centre and was regularly attended by Betsy, Sherry, seven teachers, and two FSU graduate students. Two books were selected by the teachers and served as a basis of discussion at these meetings (Chaille & Britain, 1991; Duckworth, 1986). Betsy commented on how she felt the seminar helped form a supportive learning group:

> After reading an agreed upon text to begin discussion, we talked about theory, related case studies from our own classes, compared experiences about how we all learn, and tried to apply the new ideas we got from each and from our

> readings in our own way in our own classes. It was fantastic to get to hear the wonderful ideas each member had to offer and to have a chance to try new thoughts on co-workers and to get feedback! We found out quickly that constraints about- what and how we had to teach and about what was possible with our particular students and with materials already in our classrooms -didn't necessarily exist.

The teachers valued the creation of the seminar group as this had been their first chance to talk 'across grade levels' and relate with others taking risks to try out innovative teaching strategies. The seminar was also helpful to the FSU participants as they were not regarded as outsiders within this group. The group adopted the phrase of 'forming a community of learners' which reflected their appreciation that persons coming from various positions could contribute their diverse views to enhance the overall group learning.

In addition to learning in the seminar session, the teachers wanted support in their classrooms to try out innovative ideas. Scheduling constraints made it difficult for teachers to visit in each other's classrooms, however Sherry co-taught with Betsy and another teacher in their rooms to begin exploring the possibilities and usefulness of co-teaching. Several ideas for improving staff development have stemmed from this such as: open-house classrooms where teachers could freely enter rooms to observe new teaching strategies; videotaping to share in staff meetings; exchange of staff among FSU and Sabal Palm to assist in teaching; and use of teacher-developed newsletters and telecommunications (i.e., electronic-mail and teleconference) to support exchange of ideas and resources. The PPS has inspired new ideas not only to improve teacher-learning at Sabal Palm but has contributed towards redesign of the FSU teacher education program.

Restructuring prospective teacher education programs

The FSU Science Education Program has been in the process of restructuring their prospective teacher education courses since 1991. Betsy and Sherry joined as a consultants on the Elementary Science Teaching methods course (SCE 4310), Geology and Biology Course Development Teams to make recommendations for these courses areas. . In Fall of 1991, Betsy and Sherry began co-teaching SCE 4310 and developed ideas for restructuring SCE 4310. One of the major changes they planned was to involve the prospective teachers in the PPS community.

Sherry and Betsy shared a concern that prospective teachers were spending too much time observing classroom teachers and listening to university lecturers in teacher education methods courses and not enough time in classrooms with practising teachers. During student-teacher field experiences, classroom teachers are often so busy there is little time to engage in reflective conversations with the prospective teachers about their practices. The prospective teacher may replicate practices observed while a practising teacher may continue with previous routines, and neither teacher learns ways to think critically about their teaching beliefs to construct new ideas to enhance their professional practices. Betsy and Sherry believed prospective teachers and practising teachers might benefit by collaborating in classroom research. They planned to involve the prospective teachers in a small group teaching in Betsy's classroom and work collaboratively with PPS seminar participants to carry out research in their classrooms.

The following sections present what Sherry and Betsy (the authors of this paper) learned about involving prospective teachers in collaborative research at the PPS.

* Co-teaching encourages reflective dialogue among prospective and practising teachers. In the Spring semester of 1992, the third meeting of SCE 4310 was held in Betsy's kindergarten classroom. The intent of the session was for the SCE 4310 participants to involve the students in a learning activity and to reflect on the experience afterwards. After an introductory drawing activity, the prospective teachers worked in small groups with the students in an experiment involving the transfer of eggs into bottles using a fire wand. A crucial lesson arose as Betsy took advantage of a "teachable moment" and continued the investigation as the kindergartners wanted to explore more about fire. This type of learning opportunity could merely be described in a university lecture on learning-theory, but there in the presence of kindergartners, the prospective teachers observed theory and practice intertwined.

The following excerpt from the discussion which followed the teaching activity was quite reflective and collegial:

> A 4310 participant: I learned that you can make up a lesson plan but it might not go how you've planned it to go.
>
> Sherry: I wasn't sure what to do when Betsy advised me that kindergarteners might not be able to draw a scientist. I just quickly thought to have them draw themselves as learners. I wasn't sure how that would turn out. I think I looked disorganized- but I don't always know what to expect. What did you all think of that?
>
> A 4310 participant: I liked watching how you [Sherry] had to think about how to adapt the activity for the kindergarteners on the spot. And [Betsy] just took up when we couldn't think of where to go next in leading the students in the egg experiment.
>
> A 4310 participant: That was so great! But how did you [Betsy] know where to go with it? I mean when the students began asking all those questions I wouldn't have been able to answer them. How did you know where to go with it [the open-ended inquiry] and how far to go with it?
>
> Betsy: "Well, I was just responding to what they seemed interested to learn in. I knew we had talked about fire recently so we were building on their prior knowledge."

The stance among the participants was that of colleagues with diverse backgrounds sharing their ideas about teaching. As co-learners we could engage in a collegial discussion and critically review our teaching practices, share innovative ideas, ask questions and pose suggestions of how things might be done differently. This type of interaction may improve how prospective teachers learn about teaching as they develop understandings about how reflective practice can occur in the context of a classroom.

* Prospective teachers believe teachers are taught methods for teaching science. Several teachers in the PPS seminar group were interested to engage in action research. Not everyone in the group had participated in the action research conducted the

previous year, thus the teachers varied in their understanding, confidence, and purpose of participating in this endeavour. One teacher had wanted to observe how kindergartners use objects and communicate their ideas as they work. Another teacher wanted to develop ideas for using a science kit which had been virtually unused in her classroom for several years. Betsy was interested in developing alternative assessment strategies and planned to involve the prospective teachers in videotaping activities and interviewing students in her classroom. The idea of involving the prospective teachers in the research initiated plans to incorporate collaborative research into the SCE 4310 syllabus for the next semester, Spring 1992.

In the fourth week of the Spring semester, the 4310 participants met with the PPS groups to begin their collaborative research projects. The practising teachers could meet only during their planning period, lunch, or class time which required our two-hour class session to be an open session. After meeting for the first time, many 4310 participants returned to the meeting site expressing confusion and frustration. A 4310 participant from one group returned and wrote the following journal entry:

> Right now I feel confused about what Ms. J. is assigning us to do as our teacher research project. From what I can tell she has a kit in her classroom and that she wants to put to use. The box is really a great resource and has a lot of really neat things. Ms. J. just doesn't know how to use it. It seems to me that she wants us to use the materials to come up with a large variety of lessons that she can teach. I am stressing out about this because I do not have any idea of how I can just come up with science lessons from the materials. I feel that's why I am in school is to learn how to come up with lessons.

This participant seemed unsure of what possible science activities could be done with the materials although the publisher's teacher's guide was also provided with the kit. Several other 4310 participants expressed discomfort and disapproval of working with teachers on projects requiring help to design lessons. At the fourth collaborative research session, the 4310 participants appeared distressed and class began with an intense discussion concerning overload of assignments required in other methods courses and the stress of performing during their two-week teaching experience. One student made the following statement:

> I see the purpose of doing the collaborative research project and I think it's probably a good idea for pre-interns to do it. But I don't know how to do research since I've only been asked to do one research project since I've been in school [in teacher education at the university]. To be honest, I hear you constantly tell us to be learners but I don't know that I've ever really been a learner. I'm 22 years old and I don't know that I've ever really "learned!" I've always been told how to do things and so I don't know what to do when you ask me to learn!

The 4310 participants decided that they were not able to learn from the collaborative research projects- primarily because they felt this activity was not teaching them to teach. Many of the prospective teachers disapproved of having to "plan on the spur of the moment" as they envisioned themselves beginning the school year prepared with an abundance of activities developed in methods courses and over the summer. They did not seem to understand the nature of science nor were they aware of the contextual conditions involved in planning for teaching and learning science. Most of the prospective teachers also indicated that they had no prior experience doing research and felt unprepared to engage in the activity. A vote was taken to discontinue the research involvement and return to the university classroom as 4310 participants had requested "to be taught more about teaching science".

CONCLUSION

Results of an informal survey indicated the majority of 4310 believed collaborative research could be a useful learning experience but it needed to be more organized. Structural conditions such as schedules of classroom teachers, meeting university class times, transporting to another campus, locating a meeting site for 4310 where groups could meet to talk and use curricular resources, and parking at the university had made it difficult to coordinate the research activity. Also, perhaps the seminar group should have discussed research methodology issues and developed their ideas more fully before involving the prospective teacher groups. The collaborative research groups had been also rushed to initiate their work in order to accommodate schedules (i.e., prospective teacher two-week teaching period, Spring holiday at Sabal Palm) which limited the degree to which pre-planning might have been able to prevent or overcome potential difficulties. Several 4310 participants also commented that more time was needed to "get to know the teachers" so they could relate to each other better and develop a sense of collegiality

Several changes and new ideas are being considered to better support collaborative research activities. Time constraints continue to pose the most challenging problems. The PPS group is reconceptualizing how events are scheduled at Sabal Palm and FSU and how additional persons can be involved in classroom teaching to permit more interchange among participants. Scheduling conditions have tended to be inflexible, however more university persons are becoming interested to participate in co-teaching and support action research at Sabal Palm. Several new arrangements have been proposed such as: designating a place on the school campus for the PPS research groups to meet freely to plan and discuss issues; using practising teachers more like a principal investigator assisted by prospective teachers in the collection and analysis of data; finding more practical ways for busy classroom teachers to collect and analyse data; creating a forum for teachers to regularly present their research in forms which are useful to teachers (not necessarily formally written articles); and encouraging visiting community members to bring diverse perspectives to enrich possible views to be considered by PPS participants. Sabal Palm PPS is a dynamic model constantly evolving as participants continue to find new ways of dealing with issues and explore alternative ways to enhance their practices.

Implications

The teachers of Sabal Palm believe that teacher-learning in a PPS has been quite different from traditional staff development opportunities. Traditional teacher workshops and teacher education classes have tended to be prescriptive and ignore how teachers make sense of their practices within the context of teaching. The PPS encourages educational practitioners to reflect on their practices and to become change agents for educational reform. However, teachers can not work alone to effect change as they will have to deal with social, cultural and political factors in the school community. In forming a community of learners the PPS brings people from various institutions together to interact so that diverse perspectives can serve as a basis creating new ideas and ways of practice. We are likely to make many mistakes as we adapt new practices and will need to be patient to work through times of uncertainty and misunderstandings. Developing collegial relationships and learning to work collaboratively will not happen instantly or automatically. Time will be needed to learn how to communicate in ways which bring together diverse perspectives and ensure that one group does not impose its values upon another. Finally, visions as there are likely to be several in a PPS, are developed among colleagues seeking to enhance learning for all. In a PPS learning community we need to maintain our primary focus which is creating schools as centers to promote learning as a meaningful activity for all persons.

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REFERENCES

Chaille, C. & Britain, L. (1991). The young child as scientist: A constructivist approach to early childhood science education. New York: Harper Collins Publishers.

Dana, N. (1991). Four walls with a future: Changing educational practices through collaborative action research. Unpublished doctoral dissertation, Florida State University.

Duckworth, E. (1986). "The having of wonderful ideas" and other essays on teaching and learning. New York: Teachers College Press.

Gitlin, A. (1990). Educative research, voice, and school change. Harvard Educational Review, 60 (4), 443- 466.

Holmes Group. (1990). Tomorrow's schools: Principles for the design of professional development schools. East Lansing, Michigan: Author.

Kemmis, S. & Carr, W. (1983). Becoming critical: Education, knowledge and action research. Philadelphia: The Falmer Press.

Koerner, M. (1992). The cooperating teacher: An ambivalent participant in student teaching. Journal of Teacher Education, 43 (1), 46-56.

Rushcamp, S. & Roehler, L. (1992). Characteristics supporting change in a professional development school. Journal of Teacher Education, 43 (1), 19-27.

Schon, D. (1983). The reflective practitioner. San Francisco: Jossey-Bass.

von Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. Synthese, 80 (1), 121-140.

Winitzky, N., Stoddart, T., and O'Keefe, P. (1992). Great expectations: Emergent professional development schools. Journal of Teacher Education, 43 (1), 3-18.

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PRIMARY PRE-SERVICE TEACHERS' PEDAGOGICAL REASONING SKILLS

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ABSTRACT

This paper discusses a preliminary investigation into primary pre-service teachers' pedagogical reasoning skills. Results from this investigation led to the development of a problem-based learning model which focused on improving primary pre-service teachers' pedagogical reasoning skills. The problem-based learning model uses pedagogical reasoning as the basis for creating problem situations for the pre-service teachers to investigate. The paper reports on pre-service teachers' views on the use of the approach to improve their pedagogical reasoning skills.

INTRODUCTION

In recent years, attempts have been made to establish the types of knowledge required by teachers to enable them to be effective classroom practitioners. This knowledge is especially important when interpreting and generating teaching alternatives and establishing the basis for particular actions in the classroom situation (Barnes, 1989; Shulman, 1987). A framework for the knowledge base for teaching (Shulman, 1987) consisted of seven categories, namely content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners, knowledge of educational contexts and knowledge of educational ends.

Teachers not only need a knowledge base for teaching but also require the ability to transform knowledge into pedagogical content knowledge. A model, defined as pedagogical reasoning, has been developed by Wilson, Shulman and Richert (1987) to describe this transformation process. Their pedagogical reasoning model has six components:

*	Comprehension:	understanding of ideas
*	Transformation:	interpreting, representing and adapting subject matter for teaching
*	Instruction:	teaching performance
*	Evaluation:	student understanding of ideas/concepts
*	Reflection:	review of own teaching
*	New Comprehension:	new understanding of pedagogy, subject matter, teaching

The importance of both the knowledge base for teaching and pedagogical reasoning has implications for teacher education programs. Various authors (Barnes, 1989; McDiarmid, Ball & Anderson, 1989) have recommended that teacher educators should help pre-service teachers understand subject matter, understand students' knowledge of specific subject matter, recognise and review the appropriateness of specific curriculum materials and develop suitable instructional approaches in topics. To achieve these competencies teacher education should be selecting more purposively the knowledge experiences to be included in initial teacher education. These four recommendations recognise that novice teachers cannot be expected to know all aspects of teaching but should be provided with a framework to reason soundly and learn from experience (Shulman, 1987).

PURPOSE OF THIS STUDY

This study was designed to establish an understanding of pre-service teachers' pedagogical reasoning skills and to subsequently try out a teaching approach using problem-based learning which addressed pedagogical reasoning skills. Two separate pilot studies were conducted. The first used interviews to identify pre-service teachers' pedagogical reasoning skills when teaching primary science. The second investigated the use of problem-based learning as a model in developing the pedagogical reasoning skills of the pre-service teachers.

THE FIRST PILOT STUDY

Method

Interviews were conducted with 14 pre-service primary teachers of whom six were completing the first year of the Diploma of Teaching (Primary); the remaining eight were in their final year of the three year diploma course. The first year students had completed a one semester unit in Science Education; the final year students had completed between 3 and 5 semester units in Science Education. Semi-structured interviews were conducted using questions which focused on the components of pedagogical reasoning.

Discussion of Interviews: First Year Pre-service Teachers

As part of the unit in Science Education, all first year pre-service teachers were required to complete a teaching activity in a school setting. The interview, which focused on this teaching experience, explored pre-service teachers' views in relation to the six areas of pedagogical reasoning.

Comprehension: Pre-service teachers considered that an understanding of the science content or subject matter was an important part of their preparation for teaching to ensure they avoided giving primary students incorrect information and to avoid embarrassment in front of a class by not knowing appropriate answers to student questions. One pre-service teacher summed this up by stating: "Really we should know it anyway. The stupid thing is they're going to spring 'Why is that going to happen?' on us. We'd look a bit silly if we just sit there."

Transformation: Curriculum materials were identified to be an important component in pre-service teachers' understanding and preparation for teaching. However, as might be expected, first year pre-service teachers, who had only a limited awareness of curriculum materials, relied heavily on teaching materials discussed in Science Education 1 or on guidance and resources supplied by the cooperating teacher when on school experience. Such an approach was indicated by one pre-service teacher who said:

> My [classroom] teacher had a lot that was useful. She just collected them up and said "Here you go, here's a handful." So I just took them and went through them.

When planning, most pre-service teachers considered the lesson from their own perspective, considering student interest and some general ideas on student ability. Planning for one pre-service teacher was quite superficial as the person was able to achieve all of these intentions by resorting to a structured worksheet available on the topic: "Well the activity I gave them I photocopied out of a book. I photocopied it and a lot of it ... what they had to do was basically there."

Concerns identified by the pre-service teachers during this planning phase related to their ability to handle the interactions with students, controlling the class, questioning techniques, confidence to teach, methods of coping with early finishers and their own limited knowledge of teaching approaches.

Instruction: Most pre-service teachers introduced the topic and during this stage described any terms and key ideas which were important to their lesson. This was then followed by the practical activity. For example, one student reported that:

> I had a basic picture book and it had a picture of a man with feathers over him and he was trying to fly and then it had the different designs of the aircraft ... and then try and use that as a means of explaining the concepts like the body shape, weight.

Evaluation: This was either not conducted or attempted in a very limited way, as typified by the following comment: "I didn't want to rate them on anything, or anything like that ... they were really bright kids, all of them were."

Reflection/New Comprehension: Most views expressed by the pre-service teachers related to organisation and student interest: "I felt quite good about it because I had everything organised beforehand, which is unusual for me", and "I think it was because it did hold their interest for that half an hour ... and they did learn something from it ... so I guess in that it was successful." Other comments focused on specific teaching techniques requiring development (e.g. rounding off lessons), ways of teaching the same topic to a whole class, and managing students working in group situations.

One area which was clearly identified as an area of concern to first year pre-service teachers was either explaining and/or adapting ideas to suit the particular class. Comments such as the following were typical: "Difficult (explaining ideas) because I don't think that I have had enough experience to be quite honest. So it was hard in a way, that if I had been stuck in there by myself it would have been really hard." Pre-service teachers had difficulty in explaining ideas as they were unable to establish alternative ways of expressing technical terms and they lacked knowledge about the students' ability and in some cases a clear understanding of science concepts at the primary level. However, they were able to identify aspects for their professional development, including obtaining ideas to introduce lessons, finding out the appropriate terminology to use when discussing ideas at different grade levels, becoming more familiar with the range of curriculum materials for primary science topics, preparing and presenting ideas to the class and developing various strategies for teaching and planning.

Discussion of Interviews : Third-Year Pre-service Teachers

Comprehension: Understanding of science concepts was still an important issue and influence on selection of a topic for teaching, confidence to teach science, teaching style and their ability to interpret curriculum materials. Prior knowledge of science developed at either secondary or tertiary level often influenced pre-service teachers selection of science topics: "I did biology in Year 12 (and have) more confidence in doing something on plants or the human body rather than technology, chemistry and physics."

As with first year pre-service teachers, content knowledge was considered important to cope with student questions, to avoid embarrassment and to ensure that appropriate knowledge is developed by the primary students. As one pre-service teacher explained, "I think that you have to have at least a certain level of understanding because even with preps the children really do ask some unexpected questions sometimes."

Transformation: Curriculum materials were interpreted in different ways by pre-service teachers. Pre-service teachers who considered that they had a reasonable understanding of the science subject matter were more likely to survey the curriculum materials and select out the parts which were appropriate. Such an approach was expressed as follows:

> I never really use them exactly how they say. I used them a lot to get ideas from, but I never did what they said to do, because we didn't have the resources available or there were too many children. So they're good to get a base from.

Alternatively, a pre-service teacher with a weak content understanding in a topic area was more likely to follow curriculum ideas more closely: "If I was weak [at subject matter] I'd stick closely to what they [the curriculum materials] say." The teaching approach was more restricted when science understanding was weak and the pre-service teachers were relying on the curriculum materials: "I do pretty basic things when my knowledge is not good," and "tend to guide them (the students) a little more structured —not open to problem-solving." Indeed for some pre-service teachers their confidence to teach science could be directly attributed to their knowledge of science concepts:

> I'm really not comfortable teaching science. I'm really happy at the lower primary level, because I know more than they do. But as the classes progress... it becomes a bit of a worry.

Other areas considered in planning included use of appropriate language, developing a lesson sequence and flow of ideas, student interest and enjoyment, and to a lesser extent primary students' knowledge in the topic. Some pre-service teachers planned highly structured lessons. Explanations for why some lessons were highly structured were: "I didn't want to cover an aspect that I knew absolutely nothing about," and "well a few times pupils go in a direction other than the way I wanted them to go. So I had to bring them back as they had to understand what I was trying to get across." In these cases, the format of the lesson was influenced by the pre-service teachers' knowledge of the science concepts.

In transforming science concepts for a particular classroom situation, finding the appropriate terminology was again perceived to be difficult as expressed by the following comments: "I don't use scientific words, but I found the words that I did use were a bit too difficult... or the way I put them together."

Instruction: Pre-service teachers did ascertain student understanding at the start of their teaching. Some were willing to adapt and modify their lesson based on student ability and interest.

Evaluation: Student learning was ascertained by the questions asked during the lesson, by listening to student conversations and by reflecting on the change in class understanding from the beginning to the end of the lesson. One pre-service teacher did not evaluate and another pre-service teacher found this an area that she still found difficult: " It is one of the problems that I have. I'm not always sure how to do it. I've just been focusing on a way ... like either listening to things they have said ..."

Reflection: When reflecting on their lessons the pre-service teachers discussed aspects such as their teaching performance, the need to develop an understanding of the science concepts and an awareness of the individual time needed to prepare science lessons.

New Comprehension: Discussion centred on children's interests in the topic, the need for better explanations of ideas, improvements in planning, timing in lessons and presentation of ideas. During the interviews, third year pre-service teachers identified areas that they considered needed more attention during their training. Skills in planning, use of various teaching strategies, a better understanding of curriculum materials, and more skills in adapting ideas to suit particular grade levels were cited.

THE SECOND PILOT STUDY

This study was designed to address some of the issues discussed by the pre-service teachers in their interviews, in particular on the development of pre-service teachers' pedagogical reasoning skills. Problem-based learning was considered as a possible teaching approach which would provide the necessary framework for the pre-service teachers to develop their pedagogical reasoning skills.

What is Problem-based Learning?

In problem-based learning the information is centred around a problem rather than an academic discipline. Through the process of working toward an understanding of the problem, students develop the knowledge, which can be applied to the problem (Woods, 1985). Ideally the problem should be developed by the students (Abel, Margetson & Sauer, 1985), but in many programs the problems are designed for the students to attempt, taking into consideration the nature of the content material that would be the focus of the problem situation. The problem becomes the motivating force for learning and acknowledges the base experiences of the learner, allowing the focus of the activity to be on knowledge construction (Boud, 1985). Problem-based learning enables students to operate at their own cognitive level, takes into consideration the prior experiences of the learner, and can lead to a higher level of motivation, self-instruction and achievement when compared to didactic teaching approaches (Wheatley, 1989; Boud, 1986).

METHOD

Two groups of approximately 20 second-year pre-service teachers, taking the compulsory two semester unit Science Education 2, participated in the trial. The trial period extended over five two hour sessions. The problem was posed as a statement with subsequent questions given to facilitate problem resolution. Pre-service teachers were to work in groups of 3 or 4 on the task. Groups were responsible for planning their approach to resolving the problem and how they would use their time. To complete the tasks groups were required to meet outside class time in addition to normal scheduled lessons. At the completion of the unit pre-service teachers completed a written questionnaire to establish their views on the use of problem-based learning.

Pre-service teachers' responses to the questionnaire

More than 90% of respondents to the questionnaire reported favourably on the use of the teaching approach. Pre-service teachers considered their motivation to be much higher using this approach as evidenced by the following comment:

> We were given the responsibility to set up our own unit of work - no restrictions on what we included or left out. The challenge of coming up with something we could implement in a classroom was a motivation.

This motivation was attributed to the control pre-service teachers considered they had over their learning.

> It is beneficial to me. I know I learn more if I look up the information, research the topic myself, because it allows me to think in a practical context and form a decision whilst discussing with others.

Other reasons cited for the greater control included being able to pace learning, the relevance of the learning, ownership of the activity and group discussion of ideas.

One of the attributes of problem-based learning is that it allows students to develop an understanding from their current knowledge base. The importance of this aspect was clearly stated by one pre-service teacher:

> Sometimes lecturers feel they know exactly how much experience or knowledge we all have and the normal routine may be boring to some and above the level of others.

Only one pre-service teacher did not like having control over his learning. This person believed that it was the lecturer's role to provide the necessary information for teaching in the primary school.

In general, group work was perceived to be a beneficial aspect of the teaching strategy. The opportunities to share and clarify ideas in relation to science, primary curriculum and planning of science lessons, sharing the workload and research responsibilities were seen to be benefits of the approach. Some comments in relation to group work were: "It forced people to research the topic and they had to know what to talk about when informing the other person" and "I knew my team members relied on me, just as I relied on them." However, it was clearly evident that one group of three students did not have positive views on the group interaction because a reluctant contributor and a dominating member created difficulties for the group to work cooperatively. Some groups also found it difficult to find time outside classtime to complete the task.

SUMMARY

The interviews in the first pilot study, conducted after a one semester Science Education unit, indicate that first year pre-service teachers have not developed skills for many of the aspects of pedagogical reasoning described by Shulman (1987). Although comprehension of ideas and transformation of ideas were perceived to be important by these pre-service teachers, skills in these two areas were not well developed. They relied on external sources to supply the science background knowledge and curriculum materials and would use these ideas without critically evaluating their appropriateness for the grade they were teaching. As expected, first year pre-service teachers focused mostly on the instructional aspects in their reasoning process.

Although third year pre-service teachers displayed more of the aspects of pedagogical reasoning, individual pre-service teachers showed weaknesses in one or more of the aspects. However, all pre-service teachers were aware of their individual weaknesses in aspects of pedagogical reasoning and could see the need for further development in most areas. Third year pre-service teachers' comprehension of science content and understanding of primary science curriculum were identified to be significant in their confidence to teach, teaching approach and selection of subject matter. Pedagogical content knowledge development appears to be an area of concern. Most pre-service teachers had difficulty transforming ideas to suit a particular grade and in finding appropriate explanations and language to explain ideas.

Indications from the second pilot study were that problem-based learning has the potential to allow pre-service teachers to develop their pedagogical reasoning skills. When using the problem-based approach, most pre-service teachers considered that they developed a better understanding of the science subject matter, curriculum materials and planning when compared to more traditional approaches used in Science Education 2. However, this study did not establish the extent to which pedagogical reasoning changed or developed over this time.

REFERENCES

Abel, D., Margetson , D. & Sauer, C. (1985). Designing a problem-based oriented degree in informatics. In D. Boud (ed.), Problem-based learning in education for the professions. Sydney: HERDSA.

Barnes, H. (1989). Structuring knowledge for beginning teachers. In M.C. Reynolds (ed.), Knowledge base for the beginning teacher. New York: Pergamon.

Boud, D. (ed.) (1985). Problem-based learning in education for the professions. Sydney: HERDSA

Boud, D. (1986). Facilitating learning in continuing education: Some important sources. Studies in Higher Education, 11(3), 237-243.

McDiarmid, W., Ball, D. & Anderson, C.W. (1989). Why staying one chapter ahead doesn't really work. In M.C. Reynolds (ed.), Knowledge base for the beginning teacher. New York: Pergamon.

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57(1), 1-23.

Wheatley, G.H. (1989). Constructivist perspectives on science and mathematics learning. Paper presented at the First International Conference on the History and Philosophy of Science in Science teaching, Tallahassee, Florida.

Wilson, S.M., Shulman, L.S. & Richert, A.E. (1987). 150 different ways of knowing: Representations of knowledge in teaching. In J. Calderhead (ed.), Exploring teachers' thinking. London: Cassell Educational Ltd.

Woods, D.R. (1985). What about problem-based learning? Journal of College Science Teaching, 15(1), 62-64.

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PUPILS' UNDERSTANDING OF COMBUSTION

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ABSTRACT

A questionnaire survey of 300, 14 and 15 year-old pupils in England and Spain was carried out to investigate pupils' general ideas about the process of burning and their ideas about specific types of combustion, using open-ended and structured response questions. Pupils' responses were analysed and categories were defined from a classification scheme previously reported by Andersson (1990). A possible model for progression of pupils' ideas about combustion is discussed.

INTRODUCTION

A number of studies have been carried out to try to understand pupils' conceptions of combustion (Andersson, 1986, 1990; BouJaoude, 1991; Meheut, Saltiel & Tiberghein, 1985; Meheut, 1982; Ross, 1991; Schollum & Happs, 1982). Previous work has been reported at different levels of generality. Some studies describe individual pupils' responses to particular questions (Schollum et al., 1982), and others categorise responses to particular questions (Driver, Child, Gott, Head, Johnson, Worsley & Wylie, 1984). Some studies have attempted to synthesise findings by applying more general criteria to classify the responses to a variety of questions (Andersson, 1986, 1990; Meheut et al., 1985; Meheut, 1982; Pfundt, 1981). This paper attempts to take the work a step further by categorising patterns of pupils' thinking across a range of questions, and by proposing a possible model to describe pupils' progression in their understanding of combustion.

MODELS OF PUPILS' UNDERSTANDINGS OF COMBUSTION

Andersson (1990) describes a system of five categories which can be applied to pupils' responses to a variety of questions concerning both chemical and physical change:

Disappearance For example, when asked about the weight of exhaust gases produced when petrol is burnt in a car (Andersson & Renstrom, 1983) some pupils answer that some of the petrol is used up in the car and disappears.

Displacement An example is of pupils explaining the disappearance of water from a puddle on the floor, by saying that the water had penetrated the floor, i.e. it had been displaced to a different place.

Modification Meheut et al. (1985) give examples of pupils explaining the burning of alcohol and the boiling of water in terms of modification of liquid alcohol to alcohol vapour and liquid water to steam.

Transmutation Some changes are described in terms of transmutation of substance into energy, of energy into substance or of one substance into a new one, for example iron wool being transmuted into carbon during combustion.

Chemical change Ideas of chemical change are applied correctly to examples such as petrol burning, but also incorrectly to physical changes (Osborne & Cosgrove, 1983). Some pupils think that the bubbles of steam are oxygen and hydrogen gases.

Meheut et al. (1985) developed an alternative way of categorising the responses of pupils (aged 11-12) based on their ideas of conservation. There are some similarities with Andersson's categorisation scheme, but Meheut et al. also incorporate the nature of the combustible material in the categorisation system. Pupils' responses can be divided into two groups according to the nature of the combustible substance. The first group includes responses about metals, wax, water, and alcohol, which are said to melt or evaporate, rather than burn, or using Andersson's terminology, are modified. The second group includes responses about wood, cardboard, paper, alcohol and air, which are seen to burn and be changed into another substance or nothing. Using Andersson's categories, these substances disappear or are transmuted. An important feature in the categorisation of Meheut et al. is that during transmutation each substance is transmuted separately. Pupils often fail to realise that matter is interacting.

The role of oxygen and air is not dealt with adequately in either Andersson's or Meheut's model. One difficulty in interpreting responses to questions designed to elicit pupils' understandings of the role of oxygen and air in combustion is that not all pupils have a good understanding of the nature of air (Russell, Longden & McGuigen, 1991; Brooks & Driver, 1989). Brooks and Driver reported that even at age 16 about three quarters of pupils thought that air had zero or negative weight. Pupils may, therefore, conserve matter but not necessarily mass, in their explanations of chemical reactions.

Driver (1985) gives a more complete general description of pupils' 'intuitive' ideas but does not attempt to distinguish different explanatory models for different pupils. BouJaoude (1991), on the other hand, in a study of twenty, eighth grade pupils, claims that 'students' understandings about burning were fragmented, inconsistent, and at variance with scientific knowledge.' Three kinds of evidence are presented in BouJaoude's paper to support this conclusion: pupils are not consistent in describing weight changes in burning, pupils contradict themselves when answering questions about the same phenomenon, and pupils' explanations are fragmented in that they are related to separate phenomena and fail to give a general overall explanation.

Evidence given for the first of these is that some pupils said that the weight of a candle stayed the same during burning, and also predicted that the weight of the alcohol burner would decrease in burning. These two explanations are, however, consistent with Andersson's category of modification and Meheut's categorisation of a group of substances that pupils think change state on burning.

Evidence given that pupils contradict themselves, is that pupils sometimes changed their minds when describing whether a candle would stay the same weight or lose weight in burning. It is clear, however, that the focus of the pupils attention was shifting from the wax, that they saw as not changing in weight, to the wick that they saw as losing weight. It appears that these pupils had two different models for burning which were cued by the nature of the materials being burnt as described by Meheut. In a similar way Driver (1985) and Driver et al. (1984) noted that pupils gave incorrect answers about weight changes, in explaining combustion in an enclosed space, because they were focusing on particular component aspects of the problem. The 'naive' conceptions of pupils described in the models of both Andersson and Meheut also fail to take into account all relevant features of combustion in their explanations, and so the 'fragmented' nature of pupils responses might, in fact, reflect a 'naive' explanation being used. The present study explores whether pupils' responses reflect a coherent model of combustion in more detail.

METHOD

The purpose of the present study was to explore pupils' explanations of combustion both in general terms and using specific examples. This study involved two countries with different traditions of science education, Spain and England, in order to explore possible effects on pupil learning, but space constraints do not allow us to discuss this aspect in any depth in this paper.

A questionnaire, which contained nine questions, all of them open and one also containing a fixed response item, was developed through a series of four pilot studies which involved about 150 pupils in Spain and England. The main foci of the questionnaire were: the requirements; the process; the products, including aspects of conservation; and the examples of combustion that pupils give. The questions which are the focus of this paper are given in Fig. 1. The questionnaire was administered to 300 pupils aged 14 and 15 in Spain and England. This number allows pupils with similar types of explanations to be grouped together. This age was chosen as all the pupils would have studied some elementary chemistry, including combustion. The pupils were selected from schools to give a sample which was representative of the two countries.

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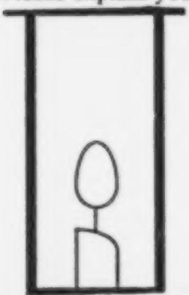
1. (a) Please explain, in your own words, what you understand by the word 'burning'.
   (b) What happens to a substance when it burns?

5. Is anything produced when wood burns? Yes No Don't know
   Please explain your answer.

6.



The candle in the gas jar goes out after a few seconds.
(a) What do you think has happened to the wax of the candle?
(b) What has happened to the air in the gas jar?
(c) Is anything formed that you cannot see? Please explain your answer.

7. When a match burns, you see a flame. What is the flame made of?

9. A student heated 6g of magnesium ribbon in a crucible and it burnt to form a white powder. At the end of the experiment the student weighed the burnt magnesium and found that it now weighed 10g. Why did the weight increase?

A. The oxygen of the air mixed with the magnesium, and because of this the weight increased.
B. When the magnesium was heated, it expanded and so its weight increased.
C. The magnesium reacted with the oxygen of the air, and because of this the weight increased.
D. The magnesium gained heat from the flame, and because of this the weight increased.
E. The result is impossible. The weight cannot have increased.

Please explain your choice.

Fig. 1 Condensed version of selected questionnaire items

The questionnaire was analysed iteratively as follows:

- Responses were analysed by developing systemic networks (Bliss, Monk & Ogborn, 1983) to capture the meanings of the responses in a systematic way.
- The networks were analysed to identify indicators of different categories of thinking.
- These indicators were used to modify Andersson's categories and to generate detailed descriptions of different categories of thinking.
- Based on these categories, a possible model (focusing on only two aspects) of pupils' progression in understanding combustion was proposed.
- The detailed descriptions were used to categorise pupils' responses question by question.
- Finally the categorisation of pupils' responses to six of the questions was used to allocate the pupils to different explanatory models and to evaluate whether the pupils were using a coherent way of thinking across questions.

RESULTS

Difficulties in categorising the data

A network was created to capture the meaning of the pupils' responses for each of the questions. An attempt was then made to apply Andersson's categories to the data but the following problems were encountered:

- the responses of individual pupils to a question often contained statements that can be allocated to more than one category;
- many statements made by pupils were descriptive and could not therefore be allocated to any category of explanations;
- pupils often used words in ways which differed from science teachers.

We treat the 'Disappearance' category as a limiting form of 'Transmutation', where the material is transmuted to nothing, as in Andersson's (1986) paper. The 'Displacement' category did not seem to fit any of the data in the present study. The analysis of pupils' explanations in this paper has, therefore, been based on the categories 'Chemical reaction' (C), 'Transmutation' (T), and 'Modification' (M).

Operational definitions of pupils' explanations

In view of the difficulties with applying Andersson's categories, it was decided to use the data encapsulated in the networks to generate operational definitions of the explanatory categories. These operational definitions are divided into three themes and are given in Table 1. In addition to the three explanatory categories described in Table 1 there is a further category of description (D) in which pupils simply describe what they see. There may be a limited amount of inference based on the observations, but no underlying explanation of combustion, e.g. if a substance burns away to an ash, they may expect it to weigh less because it looks as though it should.

A hierarchy of children's ideas

Comparison of the operational definitions with scientists' accepted explanations suggests a hierarchy of explanation from (D), as the furthest from accepted scientific explanations, through (M) and (T), to (C) which is a simple scientific view. With (D) pupils see no need to explain what they observe and simply accept the world as it is. In category (M) pupils fail to distinguish between chemical and physical change and so have no generalised view of burning: some examples of burning they see as physical changes such as melting and evaporating, and others they see as permanent transformations. Category (T) is also an explanatory model, but one which fails to take into account the interaction between the combustible material and oxygen/air. It does, however, recognise that the products of combustion are chemically different from the reactants. Category (C) is a simple chemical explanation of combustion.

TABLE 1
OPERATIONAL DEFINITIONS OF PUPILS' EXPLANATIONS

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1. Role of oxygen/ interaction

    C: Pupils recognise that the combustible substance and oxygen/air interact. The reaction is irreversible.

    T: There is no interaction between the combustible substance and the oxygen/air. Oxygen/air may be or may not be recognised as necessary for combustion to take place. Burning is a destructive process. The destructive process may release or liberate substances from the combustible substance. It is irreversible.

    M: Oxygen/air is not involved in the change. The change is reversible.

2. Flame/fire

    C: Energy changes may be observed but are not explained. The flame/fire is evidence of a chemical reaction. The flame contains both the combustible substance and oxygen/air reacting.

    T: The flame/fire is an active agent of change. Air/oxygen may be needed to 'feed the flame' or 'keep it alive'. Air/oxygen is transmuted by the flame/fire or is consumed by it. Matter may be transmuted into heat. Flames contain only the combustible substance or oxygen/air or possibly both but with no interaction.

    M: The flame/fire is a source of heat to make the modification occur.

3. Products and reactants

    C: The products contain the reactants in a different chemical combination. Mass is conserved provided that pupils think that gases weigh something or gas is not 'lost' to the atmosphere. Properties are not conserved.

    T: Substance is changed from one substance to another or into nothing during combustion. Oxygen/air may be transmuted separately into a product. It may be needed but does not interact in a chemical sense. Mass may increase, decrease or stay the same (because the transmuted products are different from the reactants). Properties are not conserved. Properties may be substantialised and therefore be involved in the transmutation.

    M: One substance changes to a different form of the same substance. Substance is conserved. Mass may be conserved, but this depends on whether different forms of the same substance are considered to weigh the same. Some properties are conserved.

A possible way of combining the categories to give an overall picture of pupils' thinking about combustion is given in Fig. 2. Progression is represented by moving diagonally from the bottom left of the figure to the top right. There are two aspects to progression: the development of ideas about interaction (vertical axis), and the development of a generalised view of burning (horizontal axis). The category of description has been placed around the left and bottom of the figure to indicate its lowest level in the hierarchy of explanations. In this study we have investigated the extent to which it is possible to allocate pupils to any of the four boxes shown.

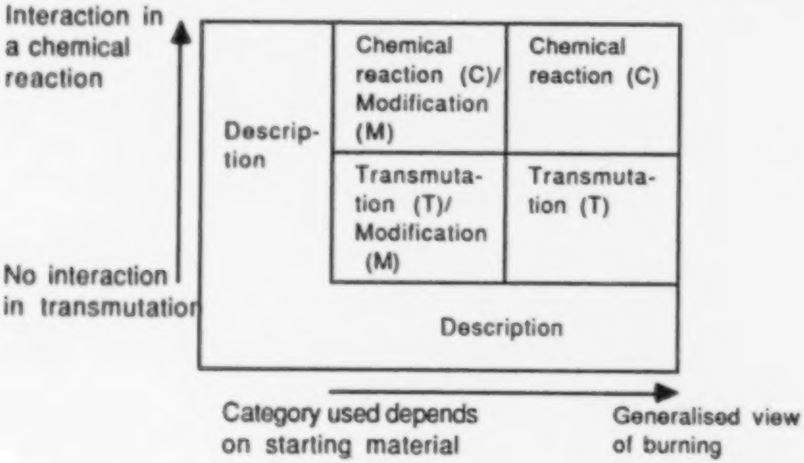
Interaction in a chemical reaction
No interaction in transmutation
Description
Chemical reaction (C)/ Modification (M)
Chemical reaction (C)
Transmutation (T)/ Modification (M)
Transmutation (T)
Description
Category used depends on starting material
Generalised view of burning

Fig. 2 A model of progression

The distribution of responses across explanatory categories

Questions 1, 5, 6, 7 and 9 were used to decide which explanatory category pupils are using in each question. Pupils' responses were allocated to a category if they used one or more indicators of a particular category in their response.

Sometimes it was possible to distinguish only whether pupils were using (M) or (C)/(T), but not between (C) and (T). These responses were categorised as (X). Some pupils provided much information which enabled their responses to be allocated to a particular category with confidence. For other pupils less information was available. Nevertheless the operational definitions in Table 1 allowed the responses to be categorised reliably. The responses of a 10% sample of the pupils were categorised by two independent coders with 94% agreement.

The responses from England and Spain are similar in quality, although there are some differences in the distribution across the categories. The dominant category for most questions is transmutation, with some pupils beginning to move towards the chemical reaction category. A very small percentage of pupils uses the chemical reaction category consistently across all questions. The modification category is very frequently used with the candle wax question, but is used by only a few pupils in other questions. Many more responses can be allocated to the chemical reaction category in Q. 9 than in other questions. This is probably because it offers a choice of fixed response explanations, which helps the pupils to answer correctly. Interestingly, this question also has the highest rate of non-response, perhaps indicating that none of the answers offered fitted those pupils' understandings.

The distribution of pupils according to use of chemical reaction and transmutation categories

The responses of pupils to individual questions have been combined in order to try to elucidate models of pupil thinking. Fig. 2 has been used as a guide for this. In this section responses using the chemical reaction and transmutation categories are considered, and then in the next section combined with the modification category to give an overall picture of pupils' thinking. Pupils' responses to individual questions, have been combined to form three groups of pupils: pupils who generally use chemical reaction explanations, pupils who generally use transmutation explanations, and an intermediate group of pupils who use both type of explanations. There is also a fourth group of pupils who rarely explain, but simply describe. The combined categories are summarised in Table 2.

TABLE 2
COMBINED CLASSIFICATION OF PUPILS
WITH RESPECT TO TRANSMUTATION/CHEMICAL REACTION

1. Chemical reaction
    (i) 3 or more C + others, (ii) 2 or more C + others which are only X (iii) C for question 9, obtained by choosing option (a) or (c), plus an explanation which includes information not in the stem of the question which also indicates category C.
2. Intermediate
    (i) 2C + some T, (ii) 1C + some T, (iii) Some C + some X + some T, (iv) 3 or more X.
3. Transmutation
    (i) All T (3T, or 4T, or 5T, or 6T) (ii) Mixed T & X (3T + 1X, or 4T + 1X, 2T + 2X)
4. Others
    2 or fewer explanations: responses mainly descriptive.

The distribution of pupils across the combined categories is shown in Table 3. Over half (54%) consistently used the transmutation model; very few (2.7%) consistently used the chemical reaction model; a quarter (24.7%) gave responses that varied from question to question and seemed to be in a transition stage in which they were moving from the transmutation model toward a chemical reaction model.

TABLE 3
DISTRIBUTION OF PUPILS ACROSS COMBINED CATEGORIES

Combined category	Number	%
1	8	2.7
2	74	24.7
3	164	54.8
4	53	17.7
Total	299	100.0

The responses from one pupil illustrate the transition stage. The letters in brackets indicate the categorisation of each statement:

Q1 (b) When a substance burns it becomes ash and releases carbon dioxide and other gases. (C)

Q5 When wood burns it turns to ash and, whilst burning releases carbon dioxide into the atmosphere. (X)

Q6 (a) The candle begins to melt, but does not burn. (M)

Q6 (b) The air inside the glass jar is needed to keep the flame alive, and when used up is replaced by the carbon dioxide... (T)

Q6 (c) [Is anything formed that you cannot see?] Yes, carbon dioxide: fire is just like man. Breathes in air and releases carbon dioxide. (T)

Q7 [When a match burns, you see a flame. What is the flame made of?] The material burning and air. (X)

Q9 Option (e) was chosen with the following explanation: The weight could not increase. You are using up the substance and therefore the weight must decrease. The substance was being used as a fuel, the result must be impossible. (T)

These responses could be interpreted as being 'fragmented and inconsistent' (BouJaoude, 1991), but it seems more reasonable to explain them in terms of a pupil struggling to develop a new explanatory model to replace one which is no longer adequate to explain the range of phenomena.

The relationship between chemical reaction/transmutation and modification

In order to examine the relationship between the two variables in Fig. 2, a contingency table has been constructed with a similar format and is shown in Table 4. In this table the combined categories from Table 3 have been used. Categories 2 and 3 have been added together to give one larger group of pupils with some understanding of a chemical reaction, as compared with a second group of 'transmuters'. In a similar way, the 'modifiers' have been divided into two groups, low 'modifiers', who have only been coded in the modification category for one or less questions, and high 'modifiers' who have been coded in the modification category in two or more. The pupils who gave few explanations in Table 3 (combined category 4) have not been included in Table 4, which shows how different types of explanations can be combined.

TABLE 4
RELATION BETWEEN CHEMICAL REACTION/TRANSMUTATION
AND MODIFICATION

	High modifiers	Low modifiers	Total
Chemical reaction or transition	8	75	83
Transmuters	33	130	163
Total	41	205	246

In Table 4, there are more pupils than expected in the cell labelled as low modifiers with chemical reaction or transition, and in the cell labelled high modifiers with transmutation ($p < 0.05$). Nevertheless, some pupils (8 pupils) have some understanding of chemical reactions, but fail to recognise some processes as burning. Many can also recognise a wider variety of burning processes as permanent changes rather than modification, but have a weak understanding of the nature of that permanent change (130 pupils).

DISCUSSION

The separation of pupils' explanatory models of combustion, as shown in Fig. 2, allows sense to be made of seemingly fragmented responses. In order to make progress along the horizontal axis pupils have to be able to recognise the difference between a permanent change, like combustion, and a temporary change, such as a change of state. In their responses many pupils concentrated on the perceptually obvious features of changes such as wax melting. They did not see the wax as being used up or interacting with the air. Similarly some pupils explained the gain in weight of magnesium by concentrating on one perceptible feature of the change, the change in appearance of the magnesium, and at the same time failing to choose options involving invisible air. In order to make progress along the vertical axis pupils have to come to abandon transmutation explanations which are no longer able to explain the variety of phenomena which they have met, and to adopt a completely new kind of explanation, that of a chemical reaction. Many pupils are in a transition phase in which they are using both models at the same time. Key features that pupils need to consider in the transition are conservation of matter, the role of gases in chemical transformation and conservation of mass. Pupils have to realise that one kind of matter cannot simply be transmuted from one substance into another; that the substances present as reactants are still present in the products but in a different combination. A concentration, by pupils, on only perceptually obvious features, such as wood changing to ash, encourages the use of the transmutation model: most pupils made no mention of oxygen or air as an important feature in the burning process. Similarly, responses to questions about products of burning were characterised by a strong emphasis on immediately perceptible products, usually ignoring any gases produced. An important role for chemistry lessons is, therefore, to extend the range of observations that pupils make about burning to include an emphasis on the involvement of gases in the reactions. An understanding of conservation of mass does not necessarily follow from an understanding of the role of gases in burning. Many pupils think that a change in form of a substance can cause a change in mass, and in particularly that gases have zero or negative weight. Without an understanding of conservation of mass it is impossible for pupils to make sense of experiments involving weighing, particularly reactions involving gases such as combustion. Preliminary analysis of the differences in response of the Spanish and English sample indicate an important role for practical work in giving the necessary experience. Further research is required to explore the proposed model of progression.

REFERENCES

Andersson, B. R. & Renstrom, L. (1983). How Swedish pupils, age 12-15, explain the "exhaust" problem EKNA - group. Department of Education and Educational Research, University of Gotenborg, Box 1010, S-431, 26 Molndal, Sweden.

Andersson, B. R. (1986) Pupils' explanations of some aspects of chemical reactions. Science Education 70 (5), 549-563.

Andersson, B. R. (1990). Pupils' conceptions of matter and its transformations (age 12-16) Studies in Science Education 18, 53-85.

Bliss, J., Monk, M. & Ogborn, J. (1983). Qualitative data analysis for educational research London: Croom Helm.

BouJaoude, S. B. (1991). A study of the nature of students'understandings about the concept of burning Journal of Research in Science Teaching 28 (8), 689-704.

Brooks, A. & Driver, R. (1989) Progression in science: the development of pupils' understanding of physical characteristics of air across the age range 5 - 16 years, CLISP, Centre for Studies in Science and Mathematics Education, University of Leeds.

Driver, R. (1985). Beyond appearance: The conservation of matter under chemical and physical transformations. In R. Driver, E. Guesne & A. Tiberghein (eds.), Children's ideas in science 145-169.

Driver, R., Child, D., Gott, R., Head. J., Johnson, S., Worsley, C. & Wiley, F. (1984) Science in schools: age 15, Research report no. 2, APU, Department of Education and Science, London.

Meheut, M. (1982). Combustion et reaction chimique dans enseignment destine a des eleves de sixieme. These doctorat de troisieme cycle, Université de Paris.

Meheut, M., Saltiel, E. & Tiberghien, A. (1985) Pupils' (11 - 12 year olds) conceptions of combustion. European Journal of Science Education 7, 83-93.

Osborne, R.J. & Cosgrove, M.M. (1983) Children's conceptions of the changes of state of water. Journal of Research in Science Teaching 20, 825-838.

Pfundt, H. (1981). Pre-instructional conceptions about substances and transformations of substances. Proceedings of the International workshop on "Problems concerning students' representation of physics and chemistry knowledge". Ludwigsburg, 320-341.

Ross, K. (1991) Burning - a constructive not a destructive process. School Science Review 72 (261), 39-50.

Russell, T., Longden, K. & McGuigen, L. (1991). Materials Primary SPACE Project Research Report, Liverpool University Press.

Schollum, B. & Happs, J.C. (1982). Learners' views about burning. The Australian Science Teachers' Journal 28 (3), 84-88.

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A COLLEGE OF SCIENCE: BRIDGING THE GAP BETWEEN SCHOOL AND UNIVERSITY

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University of the Witwatersrand

ABSTRACT

Many tertiary institutions in South Africa have implemented schemes to help redress the unfair school educational system. This paper describes one such initiative to increase access and success of educationally disadvantaged students in science. The background of the College of Science and the success of its first intake of students is described with an emphasis on the physics component of the physical sciences course. Sixty six percent of the students passed all three courses in their first year with the most educationally disadvantaged showing the greatest gains.

INTRODUCTION

The educational system in South Africa, with its patent inequalities, has been well documented (e.g. Hofmeyer & Spence, 1989). However one of the concomitants of this system is the expectations of the few black students who actually obtain a matriculation exemption certificate - the one requirement for study at university. Of the over 1 million black pupils enrolling for the first year of primary school, less than 25% stay at school to matriculation and very few of these gain a matriculation exemption certificate. This being the case, those black students who do stay at school and the few who do gain a matriculation exemption certificate are the high flyers in their communities and are looked up to as the leaders of the future. What has concerned the 'white liberal' universities increasingly over the past few years is the very high failure rate of these students if they are admitted to these institutions. One such institution is the University of the Witwatersrand (Wits) and this paper looks at the latest in a development of initiatives to improve both access and success of such applicants to the university.

HISTORICAL PERSPECTIVE

In 1975 Wits introduced a bridging year for educationally disadvantaged students. This was developed after one or two years into a four year reduced load curriculum. (The 'normal' time required for an ordinary BSc is three years although only about 25 % of students graduate in three years). This reduced load curriculum spread the first years of study over two years and academic support was provided by tutors either in the central Academic Support Programme (ASP) or by tutors based in academic departments. The problems inherent in this arrangement were:

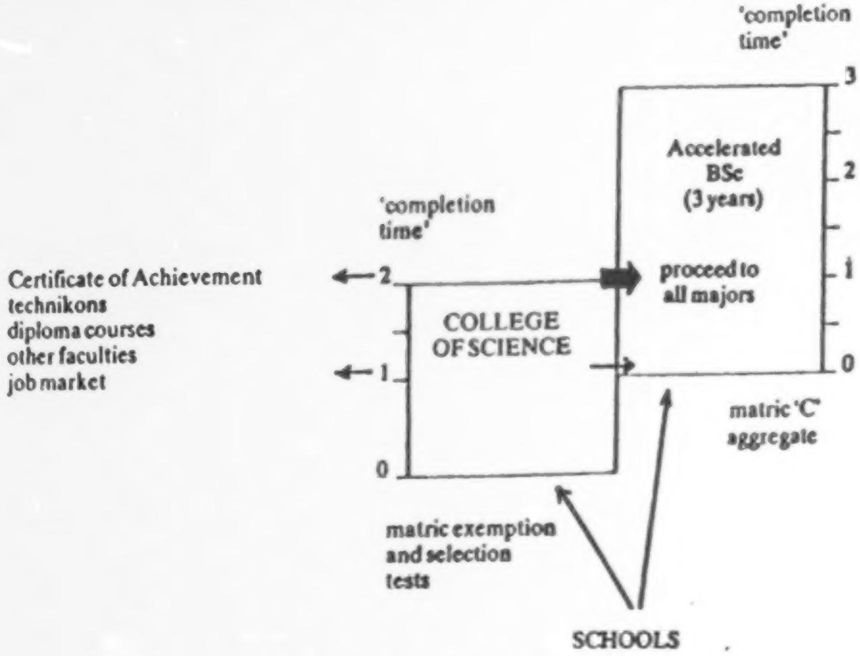
- students entering their second year of study (third year at university), often could not cope with the increased work load.
- attendance at academic support tutorials was voluntary and frequently those students most in need were those who did not attend - it was seen as an 'add-on' for people who were 'thick'. (See Bradley & Stanton, 1986)

In the late 1980's Wits, along with many other universities in South Africa, began considering the idea of a College for educationally disadvantaged students and, whilst the idea was accepted in principle, implementation across the university proved very difficult.

The Faculty of Science however decided that it could implement a College within the faculty more easily since there were certain common requirements for all science courses. These were that almost all students must take a course in mathematics and that they would all need either physics or chemistry at least at first year level. The idea of a fixed curriculum was therefore feasible within this Faculty. After months of Faculty-wide discussion and debate the idea of a College became a reality. Funding for the additional costs (mainly staffing) was obtained and the College admitted its first students in February 1991.

THE COLLEGE OF SCIENCE

Fig. 1 shows how the College interfaces with both the 3-yr BSc and with other career paths.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Accelerated BSc (3 years)
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COLLEGE OF SCIENCE
matric 'C' aggregate
matric exemption and selection tests
SCHOOLS

Fig.1 College / 3-yr Interface

Students in the College programme are full members of the Faculty of Science and, from the end of their first year may take a variety of different courses including a mixture of second year College courses and first year full university courses. All courses are credit bearing and, at the end of their second year in the College, students will have more credits than 3-yr BSc students at the end of their first year.

Admission to the College of Science

Automatic admission to the 3-yr curriculum in the Faculty of Science is based on matriculation examination results only. Admission to the College is open to all applicants who, although not meeting the requirements for automatic admission, have at least a matriculation exemption certificate and 60% pass in Standard grade mathematics.

The ethnic mix of the College embraces all the different groups within South Africa since there are various sorts of educational disadvantage, the most extreme being that experienced by those applicants from the school system reserved for black pupils.

The selection procedure

The criteria for an acceptable selection procedure are that it must

- be academically acceptable;
- be acceptable to the communities served by the University;
- select students with a reasonable chance of graduating in a reasonable time; and
- give at least an equal chance to educationally disadvantaged applicants.

The skills and abilities considered important for students studying science in a English medium institution are scientific aptitude, spatial ability, English competence and basic science and mathematics knowledge. The battery of selection tests is designed to measure these skills (Rutherford & Watson, 1990).

The College courses

In the departments of mathematics, physics and chemistry where four year curriculum courses were previously offered, the College courses are built on the experience gained from these reduced load curricula. In the other departments the courses have been informed by the ASP activities within those departments over the past few years. For the two year courses (mathematics, physical sciences, biological sciences and engineering sciences), many of the College students will write the same examinations as the three year curriculum students at the end of their two years. College students taking the Earth sciences option take the same lecture course as the 3-yr curriculum students and write the same examinations. They do however have extra tutorial and laboratory assistance.

All College courses are designed to incorporate academic support. The skills and processes which should be contextualized include study skills, language skills (e.g., reading, writing, listening), practical skills and transfer skills.

The student/staff ratio for the College is much better than for 3-yr BSc students and small group work is emphasised for many of the sessions. The approach of the various course co-ordinators varies but a short description of some of the features of the physical sciences course will give a flavour of the differences between College and mainstream 3-year curriculum courses.

Physical sciences course

In the first year of the course the intention was to integrate as much as possible the physics and chemistry components. For example, the gas laws are usually taught by both departments; in the College they are taught by the chemists with input from the physicists. The traditional lecture, tutorial and practical allocation of time is blurred when appropriate so that the students may move between activities as needed. The intention is to produce autonomous learners from students brought up in a rote learning environment. In the physics component a contract is struck at the beginning of the year between the lecturer and the students which stipulates that the students will prepare for the lecture session and any one of them may be called on during the official 45 minute session. Any student not prepared is expected to leave the class: this has not yet happened!

The intention is to shift the onus from the lecturer to the students and to make them responsible for their own learning.

CONCEPTUAL DEVELOPMENT IN PHYSICS

One of the main aims of this course was to encourage conceptual development, problem-solving and creative thinking. These are difficult goals to achieve, but there is some evidence to show that at least one aim, i.e. conceptual development, seems attainable, even with large groups of academically under-prepared students.

Approach to Teaching

The course was organised within four instructional "environments": lectures, small-group tutorials, laboratories and computer-aided instruction (CAI). New approaches were tried in the lectures and small group tutorials, but not in the other two areas.

Student-centred Lectures

This approach has been developed by van Heuvelen (1991) and Schuster (1987). The lectures are based on, and proceed from work done in preparation by the students. Students complete worksheets that present small conceptual blocks: each starting with an overview in which students learn to reason qualitatively about physical processes, using sketches and diagrams. The students will often confront preconceptions that may be misconceptions in this preparation. Similar physical processes are then analyzed in a quantitative fashion using multiple representation techniques (van Heuvelen, 1991).
The students found this approach attractive - something that conventional wisdom certainly does not predict. The dedication and motivation of the College students, apparent in their responses to the evaluation questionnaires (Donald, 1991), may explain this.

We have, however, no empirical data yet that relates success directly to this approach. It will clearly be difficult to isolate the such empirical effects but what is clear is the satisfaction both the students and lecturer felt in those instances when the approach really came together.

The most important aspect of this approach is the worksheets. These must be carefully developed: picking an interesting looking problem and reworking that into a worksheet simply did not result in the interaction in situations where the van Heuvelen worksheets were used. The obvious implication is that one needs such carefully researched worksheets to attain meaningful interactions.

Small-group tutorials to encourage conceptual development

Students met in small-group tutorials twice weekly. This was seen as the crucial component of the course, and conceptual development and problem-solving were addressed in each of the tutorials. In the problem-solving tutorials pair-problem solving was encouraged and it was suggested that tutors refrain from "giving the answer", but try to facilitate students' problem-solving. The HELP series (Ogborn, 1977) was used extensively in the mechanistic aspects in these tutorials (the "how-to" aspects).

The aim with the conceptual development tutorials was to identify difficulties and then deal with such problems via constructive teaching. Students completed short diagnostic tests at the start of a content "block". What represented a "block" was determined by the lecturer, e.g. using ray diagrams to determine image formation by lenses was regarded as one block. The problem areas identified in the tests were then worked into tutorial questions.

The effects of thorough, research-based problems and worksheets were again important. Table 1 shows the pretest post test scores for one example. 'Target' questions (Fig. 2) for a module dealing with the conceptual understanding of Newton's third law (Brown, 1989) were used.

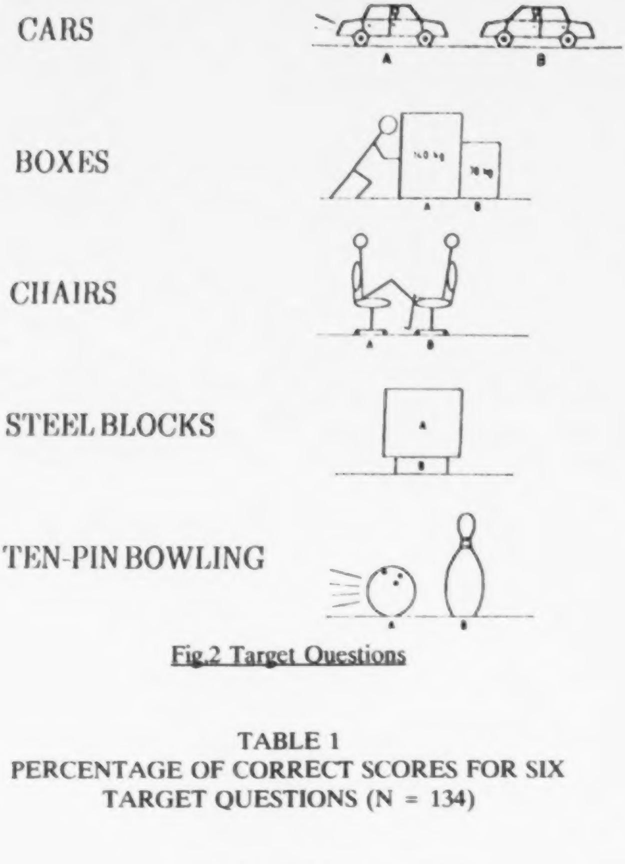

Fig.2 Target Questions

TABLE 1
PERCENTAGE OF CORRECT SCORES FOR SIX
TARGET QUESTIONS (N = 134)

	pretest	post test	change
cars	23%	36%	13%
boxes	15%	43%	28%
chairs	17%	58%	41%
steelblocks	8%	73%	65%
tin-pin bowlin	2%	3%	1%

In all but one case the post-test scores were considerably higher than the pre-test scores. The anomaly is the ten pin bowling: the only question which considered a dynamic situation. This area was not specifically addressed in the lecture sessions whereas the others were all static situations which were made explicit.

This first year in the College of Science has been instructive for the lecturers in the physics department in at least two ways:

- The need for basic, fundamental research into students' cognition: how they reason (in different content areas), what their naive beliefs are and how these influence their reasoning and their understanding are issues crucial to meaningful learning.
- Basic research (outlined above) can then be used as the foundation of instructional development (i.e. worksheets and CAI).

The kind of research described above is in its infancy in the "developed" world (Europe, North-Americas). Although basic research, perhaps "curiosity-only" research, it is imminently applicable: in fact one can argue that there is no other way to develop meaningful instruction and promote meaningful learning. It should be clear that this kind of fundamental, basic research into students' intuitive beliefs and reasoning is needed even more in an "underdeveloped" country than in the "developed" world. Students' intuitive knowledge is undoubtedly influenced by culture and environment but not, as conventional wisdom decrees, always to the detriment of scientific thinking. For example, a seminal study by Hewson and Hamlyn (1985) shows that Sotho children have sophisticated, quantum-mechanical beliefs about heat transfer - as opposed to their "first world" peers (whose beliefs are closer to 18th century caloric theories). This research begins to question the conventional ideas that African people's intuitions (and science) are less "scientific" than those of Europeans. And more importantly: the research again reinforces the notion that intuitive beliefs are crucial to the development of understanding.

EVALUATION

Do these innovative approaches to teaching and learning in tertiary education work? The traditional measure of success in academia is examination results and overall pass rates. It is not acceptable to claim that the College approaches are successful unless it can be demonstrated that the quantitative results are at least as good as the results obtained from traditional courses. The evaluation of the College therefore has two components: qualitative and quantitative.

On a qualitative level, members of staff taking second year College students report very favourably on their attitudes, enthusiasm and ability compared with the new intake of first year (3-yr) students. On a quantitative evaluation, for the first intake of College students, who must pass all three of their courses to be admitted to the second year, 66% of them passed.

If we then compare the College students with similar students on a 3-yr curriculum. we find that the most dramatic difference in pass rates occurs for the most educationally disadvantaged students (DET): 64% pass rate in the College and a 20% pass rate for students on the 3-yr curriculum. It should be remembered that the College students entered the University with much poorer school leaving marks and also had to pass all three subjects. The 3-yr BSc students only have to pass two courses to be permitted to return to the university. This being so, the difference in pass rates for these students is remarkable.

CONCLUSION AND DISCUSSION

After only one year of operation it is not possible to draw any firm conclusions, nor to make generalisations. However what can be said is that the College concept as interpreted by Wits seems to be succeeding in enabling students who in a traditional university environment would stand little chance of success, to become true learners and to succeed in science courses. The acid test will obviously be how many of these students graduate in the minimum time of four years.

REFERENCES

Arons, A. (1990). A guide to introductory physics teaching. New York: John Wiley and sons.

Bradley, J.D. & Stanton, M. (1986), Slow stream curricula in chemistry and physics. South African Journal of Science, 82 (10),537-539

Brown, D. (1989). Overcoming misconceptions via analogical reasoning. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Donald, C. (1991). Evaluation of the LASSI inventory. Internal publication, College of Science, University of the Witwatersrand.

Hewson, M. & Hamlyn, D. (1985). Cultural metaphors: Some implications for science teaching. Anthropology andEducation Quarterly, 16, 31-46.

Hofmeyer, J. & Spence, R. (1989). Bridges to the future, Optima,37 (1), 37-48

Ogborn, J. (ed.) (1977). Small group teaching in undergraduate science. London: Heinemann Educational Books.

Rutherford, M. & Watson, P. (1990), Selection of students for science. South African Journal of Education, 10 (4), 353-359

Schuster, D. (1987). A problem-centred approach to lecturing. Working paper, University of Natal, Durban

van Heuvelen, A. (1991). Overview, Case Study Physics. American Journal of Physics, 59, 898-906.

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CHALLENGING STUDENT TEACHERS' CONCEPTIONS OF SCIENCE AND TECHNOLOGY EDUCATION

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ABSTRACT

To address expected negative attitudes to studying science and technology held by primary school student teachers, we devised a learning model which combined cooperative group strategies with a learners' questions approach in a context which allowed for pluralism in methodology and epistemology. The model was used in a teacher education elective subject studied by final year Diploma of Teaching students at the University of Technology, Sydney. We found that some students were inexperienced in participating in the planning and design of their learning and that for many students, being responsible for their learning in a science and technology context aroused reactions of alarm and determined avoidance so that alternative pathways for achievement in the subject had to be offered. Some students reported feelings of satisfaction in their successful learning despite initial anxiety, low confidence or indifference.

INTRODUCTION

A new subject, Science and Technology, became part of the primary school curriculum in New South Wales in 1991. Preparation of student primary teachers for the demands of this new subject, when many already lack confidence and interest in science and technology, and/or possess an inappropriate view of teaching/learning science, poses significant challenges for teacher educators. We attempted to meet these challenges in a primary teacher education elective subject, Science and Technology in Australia, using learning methods which took account of learners' prior ideas, experiences and attitudes and encouraged learners' ownership of ideas and learning.

BACKGROUND TO THE STUDY

Evidence is accumulating to indicate that primary and student primary teachers, a mainly female population, display low confidence in teaching in the physical sciences and technological areas (DEET, 1989; Skamp, 1991). Consequences of low confidence include continuation of a cycle where negative attitudes towards science and technology of female primary teachers are transmitted to female children in their classes (Eccles, 1987, cited in Kahle, Anderson & Damnjanovic, 1991). This may in turn result in low participation of women and girls in physical sciences (Ainley & Jones, 1990; Kelly, 1987).

Critical analysis has shed light on barriers to science learning (e.g. Fensham, 1988). Three facets of that analysis are central in our planning of an inclusive learning model designed for learners who are in different states of readiness to engage in further learning in a science and technological context. Our model encompasses pluralism in views on the nature and philosophy of science, in methodology, alternative methods of teaching and learning, and context, chosen for its relevance to the learner.

Females' negative attitudes to science: arguments for epistemological and methodological pluralism

Females may be alienated from the physical sciences by factors that underlie the ways science and its philosophy are presented in secondary schools (Bentley & Watts, 1987). These factors include an epistemology which is characterised as objective, officially sanctioned knowledge built around abstract and hard ground rules, and an experimentalist/ manipulative methodology (Keller, 1985). Formalism is lauded as the only state for reasoning and not just one style (Turkle & Papert, 1992). Challenges to that dominant and singular epistemology have helped to identify an alternative view of knowledge which is "flexible and non-hierarchical and is associated with negotiation, relationship and attachment" (Turkle & Papert, 1992, p. 166). Alternative epistemologies may result in inclusive approaches to learning.

Aspects of an alternative methodology for learning and teaching

A desire for an alternative epistemology (arising from feminist and constructivist criticisms of practices and philosophies of science education) has spawned a range of learning approaches exemplified by Barnes' conversational style (1976) and Biddulph and Osborne's (1984) interactive approach. Almost in parallel development, learning in cooperative groups has attracted widespread interest from practising teachers and educational researchers concerned with psychological and social issues (Johnson, Johnson & Holubec, 1990; Sharan, 1990). These ways of learning suggest new roles for students and teachers.

In learning driven by learners' questions, students may make significant choices in their learning, negotiate outcomes and can be active in and responsible for their learning. This method was thought to be novel in the context of the previous experience of the students in our study.

When learning takes place in cooperative groups, enhanced academic achievement can result when learners work together, with group goals, group rewards and individual accountability (Sharan, 1990). The choice of a cooperative group learning environment for this study also allowed us to incorporate factors (such as cooperation, sharing, opportunity to speak freely and be accepted by peers) which are recognised as important for female learners (e.g. Kelly, 1987). These factors complement the learners' questions approach and are consistent with developing a holistic view of science in which social, ethical and moral questions are involved. As the class of 27 contained 23 females, we considered that this part of the learning model would help support learners cognitively and affectively.

Context

Context, where the learning is located, and where it becomes alive is claimed to be crucial in meaningful learning (Cosgrove, 1989). By blending the above approaches to learning with a context which itself meets demands of social relevance, we considered that learners disaffected with science and technology may be tempted to risk, and to enjoy, this scientific investigation.

We chose heat pumps as a technological context, on several grounds.

- We predicted that the impact of refrigeration on peoples' lives would appeal to female learners and its everyday familiarity and accessible technology would make its study less threatening than examining other technological systems which may carry with them an alienating effect.
- Air conditioners and refrigerators are of major importance both domestically and industrially in Australia. There is scope for inquiry into: the invention of refrigeration, how refrigerators work, the storage of food before refrigeration was invented, the historical development of refrigeration and its effect on lifestyle, scientific explanations of heat and its transfer and their relevance elsewhere and the wise use of refrigeration in this society.
- Ways of introducing refrigeration studies had been developed and evaluated (Cosgrove & Mueggenburg, 1986; Newman, 1986; Cosgrove, Newman & Forret, 1987).
- Female learners in an upper secondary class achieved high understandings in this topic (Newman, Cosgrove & Forret, 1988).

In the light of developments which will be discussed later, we should state here that we expected that this would be a scientific and technological study, calling upon our learners to interpret technical effects through scientific explanations. Although the context lends itself to study of historical and sociological issues, we did not intend these to be the focus of the students' work.

THE STUDY

Students in the subject, Science and Technology in Australia were near the end of a three year teacher education course. These students had elected not to study science discipline subjects, so for them, this background subject was their only chance to study science and technology, apart from two science teaching-method subjects. Few of them selected Science and Technology in Australia as their first choice from a set of six background elective subjects.

The project occupied five weeks of class time (three-hours per week). Although other technologies were studied in the remainder of the subject, they are not discussed in this paper.

To promote reflective analysis of events, learners kept a journal in which they recorded notes about their learning, their reactions to the sessions, notes and comments about group processes and interactions, the effects of the cooperative group on their progress, summaries of the group's deliberations from each end-of-session discussion and other information which would be helpful in their reflection.

As part of the assessment requirements, and in line with the philosophy for an aspect of cooperative learning, each group undertook a major project about refrigeration and all participants in the group presented an individual report on their learning.

Questions

The information that most of these students would have preferred to have been studying something else, suggested some research questions. Four were identified for their central bearing on addressing the issue of low participation and low confidence of females in the physical sciences.

Subject choice questions Is the preference for other electives due to:

1 lack of interest in science and technology, particularly among the female students?

2 students' lack of confidence in their ability in science (particularly the physical sciences) due to experiences in science classes at school?

Learning model questions Can we gain insight into:

3 how these students manage when they are called upon to be responsible for their own learning and achievement?

4 whether cooperative group work supports these students if they are anxious about learning science and technology?

The next section describes briefly the teaching activities arranged for these sessions and our observations of students. A full description of resources used, activities, class discussions conducted and the co-operative group strategies used for building group relationships are given elsewhere (Segal, 1991).

The teaching

Introduction: Sessions one and two Here we distributed an initial questionnaire (to gather background about the students) and explained the learning approach, including the parts groups and individuals would play in planning and learning. One third of the class missed the first session, due to unexpected internal arrangements. Therefore, in the second scheduled class we attempted to develop a shallow-end first approach with these late students too, by repeating some of the first week's introductory activities with them, prior to integrating them into groups in accordance with student preferences.

We had anticipated that groups would start to begin their own planning after further class demonstrations towards the end of session two. Instead, we observed that students were not engaged in active discussion or planning. Some students asked us again about the nature of the assessment, which we construed as displaying anxiety. The general atmosphere was one of unease and disquiet. This suspected anxiety was addressed by holding a discussion with the entire group, so that they could voice their concerns about how they were expected to go about their learning without being told exactly what to learn, and could ask questions about the nature of the assessment. We suggested how they might go about their planning.

Session three Two groups came to class at the beginning of session three, with evidence of planning undertaken during the week. Students in one of these groups, (one female and two males) had an air of excitement about them and made immediately for the refrigerators on display, to check out some understandings. As they looked at the refrigerators in the laboratory, their actions were purposeful and all three sought to find the path of the refrigerant and to discover how the thermostat operated. Other students sat passively at their tables, engaged in quiet conversation.

We introduced some additional and puzzling experiences related to refrigeration to encourage people to formulate questions. One further group (two females) could be encouraged to come with one of us (GS) to the part of the laboratory containing refrigerators and other equipment.

Sessions four and five All groups were observed to be carrying out plans for their project.

Information gathering Information bearing on possible answers to our research questions came from students' journals, assessment items, initial and final questionnaires, observation and interpretive commentary based upon our interactions with students, some of which were taped. We reviewed each class with another researcher who observed this teaching. Here we compared our construction of events from our individual observations and interpretations .

FINDINGS

The questionnaire given to the group (N=27) during the first and second session enquired into self-ratings about science subjects studied in high school, attitudes to high school science subjects, science and technology, and learning preferences. Some information is presented in Table 1 and some other findings are discussed below.

Subjects studied in years 11 and 12 Few of the group of 27 students had studied either physics or chemistry in Year 11 or 12, (both students who studied physics were male). A large number had studied no science subject in senior high school (Table 1). This data is consistent with other findings (e.g. Jane, Martin & Tytler, 1991).

TABLE 1
SCIENCE SUBJECTS STUDIED IN
YEARS 11 AND 12 (SENIOR HIGH SCHOOL)

Subject studied	Year 11	Year 12
Biology	12	11
Physics	2	2
Chemistry	5	2
General Science	2	2
No Science	10	11

Feelings about science and technology as a subject About half of the class did not rate their level of confidence, degree of interest, keenness, or level of skill positively. We sought and found a link between students who were willing to carry out a scientific investigation and previous science experiences.

Links to positive attitudes to high school science Two groups fully investigated how the fridge worked. These five students had selected this elective as first choice and reported that they enjoyed at least some part of science at high school.

Links to negative attitudes to high school science The attitudes of some of the students who avoided contact with the refrigerators were based on low interest, and apprehension about further failure after lack of success at school science. Students readily reported this in journals and in conversation.

The projects

The projects were completed after the fifth session. They included videotapes produced by students who had not used a video camera before; transcriptions of taped interviews conducted with refrigeration and air-conditioning experts; social histories of elderly people who experienced alternative methods of keeping food cold; photos taken of a refrigeration plant in a factory. In addition to information gained through library research and brochures, projects displayed artistry in presentation of both typed and illustrated material. We were impressed with the standard reached by each group.

DISCUSSION

In spite of our efforts to be non-threatening, we were conscious of student anxiety which reached a peak during session two and in the first part of session three. In the first part of this discussion, we suggest possible reasons for this anxiety. In part two, we explain how and why the pressure was alleviated. In part three, we consider our learning model and describe some outcomes which were observed, and in part four, discuss some issues related to communication and learning which are relevant to our model.

Part one: Student anxiety

Among possible contributors to student anxiety were the display of refrigerators and other equipment; the prospect of having to carry out a scientific investigation; the assessment and students' low experience of self-directed learning; what happened at the beginning of the subject.

Technology on display. Students were reluctant to approach the refrigerators to make observations and inferences about how a refrigerator works, and in some cases, this was totally avoided.

Scientific or technological investigation It was not clear whether it was the technology itself, or the prospect of investigating, or both which caused the anxiety. We suspected that this reluctance could be an example of learned helplessness in a scientific context, but this is conjecture.

The assessment and low experience of self-directed learning Students were reluctant to accept that they were able to present the results of their learning in any way they chose Later we confirmed that this was the first time that some of these students had experienced any school or university subject in which they could make significant choices.

The events at the start of the subject The students who missed the first session contributed to the developing anxiety, even among students who had been present for both sessions. This is indicated in some journal entries.

Part two: Modification of approach

The high level of anxiety and the passivity of many students meant that at that stage of development of the subject, the situation needed to be carefully assessed in terms of risks to the students to determine whether we needed to modify our approach.

Risks for students In discussing the anxiety and passivity of the students at the end of session two, we did not know if it were possible for these students to change from their dependent mode of learning, especially in a technological context. This could have meant failure in a subject in the final semester of their course.

Modifying plans Our original plan for the unit, scientific investigations embedded in historical and sociological background research, seemed alienating and non-motivating to most of these students. Faced again with mostly passive students in session three, resisting engagement with the equipment on display, we encouraged students to concentrate on other possible foci for their projects:- an historical study of refrigeration, sociological studies, including questionnaires to people of different ages and cultures about refrigeration were mentioned as choices for their learning.

After the modification The change led to more enthusiastic approaches to students' planning, shown in sessions four and five.

Part three Learning model issues

We now analyse the part played by our learning model in the outcomes of our study.

Learners' questions approach, pluralism and context These parts of our learning model provided us with flexibility to accept and act on the unreadiness of the majority of our students to plan a scientific investigation in our chosen context of heat pumps by encouraging them to ask questions of social and historical concern, within the same context. This seemed to appeal to them more. If we had been unable (or unwilling) to abandon our original plans, we think that we would have been virtually denying them access to future learning in science and technology by reinforcing their low self-esteem and confidence in this area.

Cooperative group learning Early and continual emphasis on cooperation and on learning group skills contributed to students reporting that they were enthusiastic about working in a group (as opposed to working alone) and that fellow group members supported them in their learning. Completed group projects illustrated one anticipated outcome of the cooperative learning group strategy, as the high level of attainment evident in each project was dependent upon a division of tasks and upon each member completing her/his assigned tasks.

We attribute the ultimate success of every group in managing their own learning to the flexibility of the entire model, but we found that other aspects of the learners' questions part of our teaching model were more advantageous to the learning of students engaged in scientific investigations than to the social investigators. We now take up this issue.

Part four Communication with students

The development of social, rather than scientific studies by some of our groups led them to ask different types of questions, most of which the groups themselves could set about answering without further assistance from their lecturers. This type of question seemed to limit the quality of the lecturer-student interactions which occurred in these groups and it took much longer for the growth of a relationship of trust to develop between lecturer and student.

Student-lecturer interactions The scientific investigators consulted us and engaged us in thoughtful conversation; the social investigators did not seem to need to do so. Such interactions which did occur with the social investigators seemed superficial, compared to the prolonged and shared conversations between lecturer and scientifically investigating student.

In the following extract from a taped conversation with G.S., Jim shows a form of metacognitive thinking about how his group's interaction with M.C. eventuated in the group's success and his own joy in discovering how the refrigerator works.

> I respect (that) teaching, that line of questioning and for allowing me to work something out, like it's allowing, you know, me to do my own jigsaw puzzle, you know its like a jigsaw puzzle, do them for hours, you know, but its an experience that working out for myself, that can never be replaced - its that first time - its like watching a movie for the first time -... I love watching films for the first time 'cos its one of the joys of life, you know, just: What's going to happen? Like a big action film or reading a book for the first time, you know, 'cos you don't know what's going to happen. Same as this, you don't know what's going to happen, you know a little bit, but you work from there.

This sharing of personal feelings is a way of expressing trust, which we consider to be a critical necessity in the teaching/learning situation for full development of the potential of the learner.

Development of trust During extensive teacher-student interactions, as a trusting relationship develops, students become willing to ask questions, even at the risk of questions revealing ignorance. An example of this was in a discussion with Mary, one of the scientific investigators, about the purpose of a drying tube in the refrigerant circuit. She asked

> If the drying crystals are supposed to pick up the moisture, how come they don't pick up the liquid freon?

Here Mary revealed that she believed that if crystals can absorb water, they ought to absorb other liquids. In the learners' questions approach, teachers can be placed in a privileged and sensitive position to respond to the needs of learners. In responding, we believe that the integrity of the learner must be preserved and that no damage be done to the self-esteem of the learner.

SUMMARY AND CONCLUSION

This study focused on students who had participated in a learning situation which was novel for most of them. Early anxiety (which may have originated in factors related to fear and dislike of independent investigating in a technological context) was ameliorated by removal of the necessity to interact directly with the equipment. This indicated to us that even with this soft approach (Turkle & Papert, 1992), some students were not yet ready for a forthright and direct venture into science and technology learning and that further rehabilitation would be necessary to continue to overcome negative attitudes to science and technology.

Varying attitudes to science as a result of high school experience, seem to have led students to markedly different outcomes. Some students advanced their scientific investigative skills and consequently their confidence in this area; others were not ready or willing to do so and were offered a different pathway to success. We believe that the feeling of achievement experienced by all members of the class was possible, due to the flexibility of our learning model.

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REFERENCES

Ainley, J., & Jones, W. (1990, December). Participation in science and mathematics at year 12. Paper presented at the Australian Association for Research in Education Annual Conference, Sydney.

Barnes, D. (1976). From communication to curriculum. Hammondsworth: Penguin.

Bentley, D., & Watts, M. (1987). Courting the virtues: a case for feminist science. In A. Kelly, (Ed.), Science for girls? Milton Keynes: Open University Press.

Biddulph, F. & Osborne, R. (Eds) (1984). Making sense of our world: An interactive teaching approach. S. E. R. U. University of Waikato-Hamilton Teachers College Hamilton.

Cosgrove, M. (1989). Learning science from technology. Unpublished D. Phil. thesis. University of Waikato, New Zealand.

Cosgrove, M., & Mueggenburg, G. (1986). Refrigeration: A teaching unit for form 6 physics. Working Paper No 211. S.E.R.U., University of Waikato-Hamilton Teachers College, Hamilton.

Cosgrove, M., Newman, B., & Forret, M. (1987). Teaching technology - refrigeration, an example from New Zealand's economic history. In K. Riquarts, (Ed), (1987). Science and technology education and the quality of life, Vol 2. Kiel: Institute for Science Education.

DEET (Department of Employment, Education and Training) (1989). Discipline review of teacher education in mathematics and science. Canberra: Australian Government Printing Service.

Fensham, P. (Ed.). (1988). Development and dilemmas in science education. London: The Falmer Press.

Jane, B., Martin, M., & Tytler, R. (1991). Changing primary teacher trainees' attitudes to science. Research in Science Education 21, 188 - 197.

Johnson, D.W., Johnson, R. T., & Holubec, E.J. (1990). Circles of learning: Cooperation in the classroom (3rd ed.). Edina: The Interaction Book Company.

Kahle, J.B., Anderson, A., & Damnjanovic, A. (1991). A comparison of elementary teacher attitudes and skills in teaching science in Australia and the United States. Research in Science Education, 21, 208-216.

Keller, E. F. (1985). Reflections on gender and science. New Haven: Yale University Press.

Kelly, A. (Ed) (1987). Science for girls? Milton Keynes: Open University Press.

Newman, B. (1986). Evaluation of refrigeration: A teaching unit for form 6 physics. Working Paper No 212 S.E.R.U., University of Waikato-Hamilton Teachers College, Hamilton.

Newman, B., Cosgrove, M., & Forret, M. (1988). Being cool in the cool unit or Evaluating the learning of refrigeration from scratch. Research in Science Education, 18, 220-226.

Segal, G. (1991). Science and technology in Australia: the early sessions, 1991. Paper presented at internal research seminar session, Science and Technology Education Research Group, University of Technology, Sydney.

Sharan, S. (Ed) (1990). Cooperative learning: theory and research. New York: Praeger.

Skamp, K. (1991). Primary science and technology: how confident are teachers? Research in Science Education, 21, 290-299.

Turkle, S., & Papert, S. (1992). Epistemological pluralism and the revaluation of the concrete. In I. Harel & S. Papert, Constructionism. New York: Ablex.

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CURRICULUM AND ASSESSMENT INNOVATION IN SCIENCE

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ABSTRACT

Concerns about pupils' underachievement have stimulated various curriculum and assessment innovations in recent years. One such innovation is the British Graded Assessments in Science Project (GASP). Research focusing on the implementation of GASP highlights issues about the process of educational change, and raises the question of whether innovators take into account lessons learned from past innovations. This paper reports on two case studies of GASP implementation, showing the degree to which teachers took on board the philosophy of the scheme. The results show that even volunteer teachers, familiar with GASP, exhibit barriers to change which are well documented in the literature. One conclusion is that those developing and supporting curriculum and assessment innovation should be informed by past experience, and find real ways of helping teachers to make the changes which are required to meet the demands of the innovation.

INTRODUCTION

> Educational change depends on what teachers do and think - it's as simple and as complex as that. (Fullan, 1982 p.107)

To what extent do innovators take into account the lessons to be learned from past innovations? One lesson, according to past studies of educational innovation and change, is to recognise the importance of the teacher in the change process (Dalin, 1978; Fullan, 1982; Van den Akker, 1988). Classroom research focusing on the implementation the British Graded Assessments in Science Project (GASP) reveals how, in spite of existing research evidence about teacher change and substantial contact with a central team, well documented barriers to change (Gross, Giacquinta & Bernstein, 1971; Stenhouse, 1975; Dalin, 1978) were exhibited by the teachers involved. This paper reports on the method and selected findings of the research, including extracts from two case-studies carried out in schools over a period of six months during the early years of GASP implementation. The outcomes of the research are reported fully in Simon (1989).

Graded Assessments in Science Project

GASP is an assessment scheme which was developed at a time when there was growing concern about the problem of underachievement in schools and dissatisfaction with existing methods of assessment (ILEA, 1984). The GASP scheme involves separate assessment of pupils' achievements in three dimensions of science: content, process and explorations, or problem solving activities (Davis, 1988). Through the open use of assessment criteria in these three dimensions, GASP aims to to provide 'realistic goals to aim for and more opportunities to experience success' (Swain, 1988). An important change which the GASP developers hoped to bring about was the promotion of pupil awareness of assessment criteria and procedures. For many teachers the open use of assessment criteria was 'new', requiring changes in their existing beliefs and practices.

Teacher change

Fullan (1982) suggests that unsuccessful innovations have been based on models which do not take into account the existing beliefs and practices of teachers. He identifies the use of new teaching approaches and the alteration of beliefs as being important components in the implementation of an innovation, and suggests that change consists of a dynamic interrelationship of these components. Beliefs guide and are informed by teaching strategies and activities. Dalin (1978) also identifies beliefs as important in creating 'value barriers', where 'individuals and groups have different ideologies and basic beliefs that make changes look quite different, depending on the perspective of the observer'.

In this study it was of interest to see how teachers accommodated GASP philosophy and procedures within their existing views and situations. The teachers who volunteered to use the scheme depended on the central GASP team of seconded teachers for support, not only in terms of materials and assessment schemes, but also in clarifying the assumptions underlying the scheme and for feedback about their interpretation of the innovation's philosophy. The challenges facing GASP teachers were studied to see whether this innovation, having central team support, promised to bring about real change.

METHOD

Fullan's (1982) analysis of the meaning of educational change emphasises that the teacher must be considered not only in the development of an innovation, but also in a study of change as the innovation is implemented. Many evaluation studies have been limited in scope through not looking at teachers in classrooms (Waring, 1979). The methodology adopted in this research, where the focus is on classroom interaction and the perspectives and strategies of teachers and pupils (Delamont, 1983; Woods, 1983), involves using the ethnographic techniques of participant observation and interviewing (Hammersley & Atkinson, 1983).

The study focused on two teachers in their first year of implementing GASP; Mr Arden and Mr Brown. Both teachers had volunteered to use the scheme, had been to many project meetings prior to implementing GASP and were confident in their knowledge of GASP. The two teachers taught in Inner London schools and implemented GASP with classes of twenty five 11 to 12 year olds. The science lessons of each class were observed over a period of six months, the researcher adopting a particular role with teachers, pupils, and the visiting GASP team. The research role is a significant factor in ethnographic research (Ball, 1990), and is described fully in Simon (1989). In order that the teachers would talk freely about their views and problems, the researcher adopted the role of a sympathetic experienced teacher in her conversations with them. With pupils she wanted to avoid being identified as a teacher in the school, as such an identity might have prevented pupils from giving their opinions freely, and she became a kind of 'teacher-helper' in the classroom.

Classroom observations and daily conversations with teachers and pupils were recorded using field notes. To verify interpretations from observations and interviews, audio-taped interviews were carried out with the teachers and pupils, where specific questions were asked. These interviews took place towards the end of the period of school visits. Prior to the teacher interviews, each teacher was provided with a written account of the researcher's observations and interpretations. In this way both teachers were able to respond to points in the analysis. The teacher interviews lasted for forty minutes, the pupil interviews lasted between ten and twenty minutes. Data collection also included pupils' assessment outcomes, which were copied from the record sheets and mark books which teachers used.

RESEARCH FINDINGS

The open use of assessment criteria was new for both teachers in the study. Observations of teachers' assessment strategies progressively focused on how the teachers carried out assessments and whether they communicated criteria to the pupils. Interviews with teachers showed how they viewed their communication of criteria to pupils and what they perceived to be pupils' level of awareness. Interviews with pupils revealed the level of awareness they had of the whole assessment process.

The findings presented here have been selected to illustrate the way in which teachers interpreted the 'open' aspect of GASP philosophy. A general description of the teaching approaches adopted by both teachers is followed by separate accounts of assessment in the process and content dimensions, including pupils' awareness of being assessed, of assessment criteria, and of personal progress.

Teaching approach

Mr Arden adopted a traditional, instructive approach to teaching. He used question and answer sessions together with undifferentiated worksheets and saw his teaching role as that of transmitting as much information in as short a time as possible, if necessary by 'spoon-feeding'. He believed pupils would benefit from this, though admitted his experience of an alternative was lacking. Mr Brown's lessons were organised around circuses of worksheets. The pupils worked individually while he went from group to group. Though his approach was more individualistic, it was also instructive, with an emphasis on transmitting information.

Assessment in the process dimension

In the process dimension pupils were assessed in terms of three stages of scientific activity: planning, implementing and concluding. Within each of these stages several processes were defined at various levels, including basic manipulative skills and observation skills. At the time of the study, teachers were carrying out assessments for these and other basic skills by using a checklist while pupils were on-task. The GASP guidelines for carrying out assessment of processes were:

> The assessment procedure should be carried out during the normal course of lessons, it is not a 'test' to be done at the end of a term or a unit of work. Pupils should be introduced to the assessment system at an early stage so that they know which skills are to be assessed and the criteria they need to fulfil for any particular level. In other words, pupils should know from the beginning

> what it is they are expected to achieve so that the assessment scheme becomes an integral part of teaching and learning.

Pupils' awareness of being assessed for processes

Both teachers were observed to carry out on-task assessments by taking their checklist of processes round the class and making ticks against pupils' names. Often teachers were seen to do this without talking to the pupils, the pupils were not told they were being assessed. The teachers assumed the pupils were aware of being assessed. When interviewed about his perceptions of pupil awareness, Mr Brown said:

> They know what the checklist is now and they see me do it. When they are in the act of doing it, they may not know I'm assessing them, but I think they are aware I'm standing there watching them setting up their retort stand that they're likely to be assessed on it while it's going on.

Pupils generally did not know whether Mr Arden was making assessments. They commented:

> No, we never see him do it because he goes behind our backs and watches us.

> Not really. You do sometimes because he has his bit of paper in his folder and that.

Many of Mr Brown's pupils were aware that he used a board for ticking off skills because they could tell me what it looked like. Some comments from the pupils who said they did know when they were being assessed were:

> 'Cos he has a piece of paper and one minute he'll be talking to you and then he'll be looking at the cardboard thing he's got.

> Well when he sort of leans over you can see if he's going to tick off and he'll go (she nodded) and tick it.

> Yea, 'cos when he asks you a question, and you know, he might say good and he writes something down, I've seen him.

This pupil added that she didn't know specifically if she personally was ticked, just that the teacher had ticked something. Some pupils said that when they looked at the teacher's grid they realised he had ticked them off for skills without them being aware of it at the time.

For most pupils at both schools, awareness of being assessed came as a result of the teacher standing nearby with his checklist. In many cases pupils did not know exactly when they were being assessed for processes.

Pupils' awareness of process assessment criteria

Communication of criteria for process assessments was scarcely observed in both classrooms, though it was more apparent with Mr Brown than Mr Arden. Mr Arden was observed to explain how to use the equipment, for example reading a measuring cylinder, but did not explain that the rules he was giving would be used as assessment criteria. Mr Brown did point out the assessment criteria for the measuring cylinder at the beginning of each lesson where he intended to assess its use.

In pupil interviews they were asked whether they knew what they had to do to achieve credits for various processes. Many pupils had some knowledge of the context in which they had used the apparatus for which they had credits and answered in these terms, for example for the measuring cylinder:

> We got some water and we had to pour it into the measuring cylinder and we had to measure it.

For the stop clock one pupil said:

> We had to time this thing

The nearest answer to the criteria was for the Bunsen burner:

> I had to set up the Bunsen burner for the board that we had to use for it (safety mat), and see the difference if the door (airhole) was closed and that lot.

The pupils in Mr Brown's class mostly believed that they knew how they had achieved the credit. However the descriptions were generally brief and again often referred to contexts rather than criteria. For the thermometer:

> Just read the temperature of it when it comes out of some warm water.
>
> Use it right to find out the freezing point.

When Mr Brown was asked how aware his pupils were of the criteria used for the assessments he said that he thought that they were 'most of the time', because 'whenever I introduce a piece of apparatus I set out the criteria for it.' Both teachers assumed that pupils were aware of process criteria, because practical procedures had been explained. However, though pupils knew how to use pieces of apparatus, they were not aware that what they had been told constituted assessment criteria. There was therefore a significant mismatch between pupils' awareness of assessment criteria and teachers' perceptions of what assessment criteria meant to the pupils.

Pupils' awareness of progress in the process dimension

Pupils could gain knowledge of their progress in the process dimension by looking at the teacher's checklist. They could also gain knowledge of their progress by their receipt of 'stickers'. Pupils who gained credits in some processes (manipulative skills) received stickers. Each sticker was a sticky-backed strip of paper showing the name of a process. Pupils stuck the stickers onto a sheet in their folders. In order to find out how much pupils were aware of their progress, they were asked in the interview whether they knew what process stickers they were due to receive and what skills they had been credited for. No pupils could say for certain the exact status of their process credits, even for manipulative skills which related to stickers. None knew which stickers they were due to receive, or why they had received the ones awarded. A typical answer was:

> I've got the measurer, and I've got that, I don't think I've got that, I've got four or five all together.

Assessment in the content dimension

Assessment in this dimension was similar to that which the teachers and pupils and normally experienced. A four week unit of knowledge and understanding was followed by a pencil and paper test. Pupils were therefore aware of being assessed. In both schools the tests were conducted in a formal way in silence. What was 'new' for GASP was the way in which it was intended that teachers should communicate the criteria. It was expected that teachers should show pupils the test before teaching the unit, in that way pupils would know the assessment criteria. However, both teachers in the study did not follow this procedure. When interviewed about their reasons for not doing so, they suggested that the procedure lacked value. For example, Mr Brown said:

> I haven't thought about it very deeply, it just strikes me that it makes it worthless as an assessment.

Pupils' awareness of content assessment criteria

To prepare pupils for content assessments, both teachers concentrated on 'revision'. Mr Arden gave the children 'revision lists' of the worksheets they were to revise. He also gave them lesson time for revision, where he expected them to sit in silence and revise by reading their folders and asking him questions if they had a problem. He gave up doing this after the second content test because the pupils talked and mucked about, saying it was 'boring'. They revised for homework instead. When asking them to revise, Mr Arden assumed that pupils would understand how to do this and that they had sufficient material to do it. Mr Brown sometimes gave pupils more guidance about what to revise in terms of specific areas of knowledge, but he also assumed that with this guidance they would then know what to do and also how to go about revision.

Observations of pupils and subsequent discussions with them showed that there was a lack of awareness of what and how to revise for content assessments. Revision amounted to reading through the notes in their folders or books related to the unit they had been studying in an unfocused way. The content assessments took many pupils by surprise, in that they were not as expected.

Pupils' awareness of progress in the content dimension

Another piece of GASP guidance for more open assessment was that pupils should mark their own scripts immediately, seeing their mistakes and finding out what the correct answers should be. Teachers did not trust such a procedure and took the scripts home for marking. Also, the teachers were not interested to look at outcomes closely and use assessments to show pupils where they had gone wrong. At one stage Mr Arden was shown the researcher's analysis of content assessment scripts, with details of how each pupil had responded to each question. He said he did not want that much detail, because pupils would be going on to study the next unit.

Pupils were very aware of their marks for content assessments and whether they had reached the cut-off score and therefore 'passed'. In interviews pupils were asked whether, when they saw their marked content assessments, they looked to see which answers they had wrong. Generally they looked to see which answers were wrong, but they were not very concerned to think about the correct answers.

DISCUSSION

The findings reported here demonstrate that the teachers did not change their practice to adopt the 'open' assessment procedures intended by GASP. One barrier to change was that these teachers were used to being 'secretive' when making assessments. This barrier of 'secrecy' is related to the 'values' barrier described by Dalin (1978), because it involves teachers having 'different ideologies and basic beliefs'. The research has shown that the inclination for secrecy, which was displayed not only by assessing for processes behind pupils' backs, but also by not showing pupils content assessments, and by generally not perceiving a need to make criteria and outcomes for all three dimensions clear to pupils, has resulted in a lack of pupil awareness.

The reasons for the persistence of this barrier to change are complex. In the process dimension teachers had to perceive the value of discussing on-task assessments with the pupils, making them aware of the criteria. Such awareness was intended to enhance learning, however these teachers did not appreciate the relationship between assessment and learning, nor did the GASP team highlight its importance when visiting the schools. Carrying out assessments by going round a class with a checklist was new and difficult. Teachers had to interpret the assessment criteria, felt under pressure to get as many checked as possible, and were constantly distracted by pupils' normal demands. These constraints were not conducive for lengthy discussions with individual pupils, therefore without a sense of priority for this kind of communication, or strategies for enhancing it, such discussion did not take place.

In the content dimension, teachers did not see assessments primarily as an aid to learning but as a means of gaining accreditation. GASP guidance suggested that content assessments should be 'formative', but the teachers' interpretation of this was not explored during visits from the GASP team. Teachers did focus on another aspect of GASP guidance, which was not to emphasise failure, with the result that they were unwilling to dwell on details of content assessment outcomes. Teachers felt that having given out the papers and marks, the tests should then be put aside so that all pupils could go on to the next unit. The major resistance to more open assessment in this dimension was the tendency for teachers to retain traditional views about assessment of scientific knowledge and understanding. Rather than see the problem in terms of deep-rooted beliefs, the GASP team concluded that the teachers had not read the instructions properly.

Though the desire for more open assessment was not achieved in these two cases, the use of GASP did bring about some advantageous changes. Both teachers began to take a more investigative approach in their science teaching, thought more about the processes of science, and broadened their view of assessment by using criteria. The GASP team was supportive in terms of providing general help and necessary materials, but did not anticipate barriers to change arising from deep-rooted beliefs. When problems arose in terms of pupils not achieving credits as soon as expected, or teachers feeling under too much pressure, there was a willingness to accept difficulties and adjust the scheme. However, the problems were diagnosed as arising from the scheme's technicalities and resources, not from the tensions created by teachers' existing values. These tensions could have been overcome sooner, had the central team been more aware of them. Simple questions could have helped teachers to pay more attention to certain issues. For example, after being asked about pupil awareness by the researcher, Mr Brown began to show the record sheets to the pupils. He discovered that an increased awareness of their achievements stimulated pupils to find out more about how they could do better.

One of the main questions arising from this study is why, after extensive innovation research, the research lessons have not been learned and the same problems of implementing an innovation appear yet again. Part of the explanation lies in the nature of the GASP team, another part in the nature of the involvement of the academic consultants. The team consisted of seconded teachers; so the reality as well as the rhetoric was teachers working with teachers. However, the development team were not typical teachers; they had time to think, and to internalize their expectations of the material and of the pupils, and thus they assumed that the assumptions would be as obvious to the teachers as to them; they were better informed of the developing arguments about the nature of assessment and its relation to curriculum and motivation than the average teacher, better even than teachers who volunteered to become trials teachers. The team projected their own ideas, interpretations, motivations and values on to other teachers. Even though they looked for change, and were willing to change the scheme when the need arose, they did not foresee the barriers to change which could have been identified initially by even a brief reflection on innovation literature.

The academics saw themselves primarily as consultants on content and technicians of testing; not as part of the negotiation of classroom implementation. Because the pace of the project was so fast, they realised that the team would have to make many decisions without consultation, and it was the decisions which related to the implementation of GASP in schools which were left to the team. Rather than bringing to bear the literature of curriculum innovation on the development and implementation of GASP, the academic staff consulted the team about the 'content' of the curriculum, about assessment of explorations and processes, and about the relationship of Graded Assessment levels to Examination Board accreditation.

Though the lessons of past innovations were not fully considered in the initial development of GASP, the flexibility of the later development has enabled many problems to be solved. After the first year of trials many alterations to the scheme took place, and others continued to take place in subsequent years. The innovators recognised that if the scheme was to be widely accepted, they would need to adapt it according to teachers' constraints. However, the constraints which have been taken into account are to do with time and resources, rather than with beliefs and values. The innovation development still lacks consideration of many relevant issues of educational innovation and change. The message of this research is that much more effort needs to be put into getting the findings of Fullan and similar studies into the consciousness of curriculum developers. Those whose responsibility it is to support innovation and encourage teacher change must pay more attention to the idea of making teachers sensitive to the necessity of explicitly looking at themselves, in terms of barriers to successful change. If teachers who take part because they want to change have these problems, how much more likely it is that the teacher who is forced to adapt will show them in an exaggerated form.

REFERENCES

Ball, S.J. (1990). Self-doubt and soft data: social and technical trajectories in ethnographic fieldwork. Qualitative Studies in Education, 3, (2), 157-171.

Dalin, P. (1978). Limits to educational change. London: Macmillan.

Davis, B.C. (ed.) (1988). GASP Summary Teacher's Guide. London: Hutchinson.

Delamont, S. (1983). Interaction in the classroom. London: Methuen.

Fullan, M. (1982). The meaning of educational change. New York: Columbia University: Teachers' College Press.

Gross, N., Giacquinta, J.B., & Bernstein, M. (1971). Implementing organizational innovations. London: Harper and Row.

Hammersley, M., & Atkinson, P. (1983). Ethnography principles in practice. London: Tavistock Publications.

ILEA [Inner London Education Authority] (1984). Improving secondary schools. London: I.L.E.A.

Simon, S.A. (1989). Curriculum and assessment innovation in science: A study of the introduction of the Graded Assessments in Science Project in two schools. Unpublished Ph.D Thesis, University of London.

Stenhouse, L. (1975). An introduction to curriculum research and development. London: Heinemann Educational Books.

Swain, J.R.L. (1988). GASP: the Graded Assessments in Science Project, School Science Review, 70, (251), 152-158.

Van den Akker, J.J. (1988). The teacher as learner in curriculum implementation, Journal of Curriculum Studies, 20, (1), 47-55.

Waring, M. (1979). Social pressures and curriculum innovation. London: Methuen.

Woods, P. (1983). Sociology and the school: an interactionist viewpoint. London: Routledge and Kegan Paul.

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LEARNING THEORIES AND ENVIRONMENTS: A STUDENT-INITIATED INTELLIGENT COMPUTER-ASSISTED ENVIRONMENT

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ABSTRACT

Intelligent computer-assisted instructional systems have been constructed and applied within a wide range of fields. Very few of these systems make explicit a central or set of core learning theories or learning environments upon which a system is based. However, many of these systems have implicitly employed learning theories and environments. This paper looks at a variety of intelligent computer-assisted systems with a view towards uncovering the latent learning theories they employ. The interplay of the various learning theories needed to realise a student-initiated learning environment are discussed. The central features required for such an environment to function and the limitations of realising such a learning environment due to the state of the art of present day systems are also discussed.

INTRODUCTION

The advent of artificial intelligence and the deficiencies of traditional computer-based instructional systems has brought about the development of intelligent tutoring systems or intelligent computer-assisted systems. These systems are computer programs which use artificial intelligence techniques for representing knowledge and interacting with students. The aim has been to provide students a flexible one-to-one learning environment as in student-tutor interactions. Attempts have been made to include the student's learning behaviour, and teaching and tutoring strategies. The main components of most intelligent computer-assisted instructional (ICAI) systems may be compartmentalized to include the expertise module, the student model, the tutoring module and an interface. The expertise module includes the skills and knowledge which need to be taught and incorporates teaching and learning strategies to enhance the interaction. The student model uses the student's within-lesson history and problem-solving behaviour observed by the system to trace and represent the knowledge and learning behaviour of students. The tutoring module offers instructional feedback tailored to the students' strengths, weaknesses and style of learning through interaction with the expertise module and the student model. The interface is the module that actually communicates and interacts with the student or user. Great effort has been placed in developing and producing ways to try and motivate students to interact with ICAI systems. In an effort to provide a system that facilitates and encourages learning, many of the designers of such systems have neglected the learning theories upon which the framework for such a learning environment should be based.

In this paper we review 30 ICAI systems (see Singh, 1992 for details) against 13 learning theories and 4 learning environments. The aim of this was to determine the learning theories which are explicitly or implicitly employed by the ICAI systems and the learning environments within which they operate. The 13 learning theories have been classified into 8 groups in accordance with the learning procedures implied by them (see Table 1)

LEARNING THEORIES AND MODELS

All the learning theories and models discussed basically propose cognitive change through knowledge compilation from small bits to larger functional units which may be easily modified and adapted. These are by no means alternative theories competing with each other but are theories developed for separate purposes. They may be broadly classified by their origins. Skinner's and Thorndike's theories originated through laboratory studies using controlled conditions with animals as subjects. The work of Phenomenologists, Gestaltists, Maslow and Piaget originated from the study of the maturation and motivational processes of human beings from infant to adulthood. Ausubel's, Kelly's and Constructivist theories have evolved through teaching, learning and curriculum development research in the classroom. Piaget's work has also been applied to the construction and teaching of sequential curriculum. The information processing system, schema acquisition, hierarchical organisation and the novice-to-expert model have originated from research on trying to understand and model the cognitive processing in human beings. The 13 theories and models used to classify cognitive learning are summarised.

TABLE 1:
GROUPINGS OF RELATED LEARNING THEORIES

Group	Related Learning Theories	Learning Procedures Implied
A	Skinner's Operant Conditioning Thorndike's S-R Connectionism	Stimulus-Response reinforcement through feedback
B	Piaget's Cognitive Development Kelly's Personal Constructs Schemata Acquisition Hierarchical Organisation	The gradual formation in stages, of inter-related hierarchical network of ideas through discrimination and refinement.
C	Phenomenological Approach Maslow's Development Levels	Self actualisation seen as the motivating force for personal enrichment.
D	Ausubel's Meaningful Learning	Meaningful incorporation of information through reception and discovery
E	Constructivism	Student-initiated learning bringing about the development of meaning and reorganisation of conceptions through experience.
F	Novice-to-Expert	Clarification of expert performance and assistance to novices to move towards expert performance.
G	Gestaltist Learning	Response to whole patterns or situations, interaction with total experience.
H	Information Processing	Modelling of how people think, handle, store, and retrieve information over time.

Skinner's (1969) Operant Conditioning: is the learning process whereby a response is made more probable or frequent through reinforcement or feedback. Reinforcements may be positive or negative. Complex responses are seen as the result of simple responses being built into more complicated behaviour patterns.

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Thorndike's (1949) Stimulus-Response Theory of Connectionism: considers learning as a process of linking physical (stimulus or response) and mental (something sensed or perceived) units or events in various combinations. A response is strengthened if it is followed by pleasure and weakened if followed by displeasure. Reward is generally used as a motivating factor.

The Phenomenological Approach (Coombs & Snygg, 1959): sees a person as an organism forever seeking greater personal adequacy. Self actualisation is the driving force motivating all behaviour. Learning is a function of need which is perceived as maintaining and enhancing the phenomenal self. Factors that become more self-related are more readily learned and retained than those that are less self-related.

Gestaltist Learning Theory (Bigge, 1982): considers learning phenomena to be closely related to perception. Gestaltists believe that to understand a thing, a study of its totality is required. A study of its constituent parts is not considered sufficient. Purposeful learning is seen as a dynamic process of organising perceptions to reduce ambiguity which acts as a motivating factor.

Maslow's (1987) Skill Development: theory of personality states a person possesses both lower (animalistic) and higher (human) needs. Lower needs include those for physiological survival, safety, belongingness and esteem. Higher needs include those for self actualisation and cognitive understanding. All needs can be conscious or unconscious. The goal is to try and move through the levels from unconscious incompetence, to conscious incompetence, through to conscious competence, to attain and achieve unconscious competence.

Piaget's Cognitive Development Theory (1956,1960 cited in Pinard & Laurendeau, 1969): lists five criteria which he attributes to the conditioned mental development of the mind in his theory of stages. These in order are hierarchical intransitivity of stages, integration through restructuring and coordination of states, consolidation through creating inter-connections to obtain total structures in equilibration. The final stage of equilibration involves the processes of assimilation (or association) to earlier schemata and accommodation to new requirements.

Ausubel's (1968) Meaningful Learning: can take place through reception or discovery. In meaningful reception learning the potentially meaningful task is presented to the learner in final form. It is then comprehended or made meaningful in the process of internalisation. In discovery learning the principal content of what is to be learned must be discovered by the learner before it can be meaningfully incorporated and internalised. Internalisation occurs through progressive differentiation of subsuming concepts and by integrative reconciliation.

Kelly's (1955) Personal Constructs: asserts that individuals represent knowledge using structures called constructs. A construct brings out the similarities of a set of elements and differences of the set (objects, events, situations or individuals) from other elements. A person's past experience with similar and dissimilar elements in comparison to the current elements under consideration helps him/her to perceive similarities and differences in the formation of constructs.

Constructivism (Driver & Oldham, 1986): propagates that knowledge is found or made according to the flow of experience. The sense made of any event is seen to be dependent not only on the situation itself but also on the individual's purposes and active construction of meaning.

The Information Processing Model (Gagne, 1977): describes mental events in terms of transformations of information from input (stimulus) to output (response). The processed information is briefly kept in short term memory. It is integrated in various ways with known information and enters long term memory. Retrieval of information is done through response generation using cues provided externally or by the learner.

Schemata (Rumelhart & Norman, 1981): are large well-coordinated and organised units of knowledge. Learning involves not only the development of the schemata but also building of the connections to create an organised network of structures by coding new information in terms of existing schemata or through schema refinement.

The novice-to-expert model (Bruner, 1985): observes an expert performing tasks in a specific domain to determine how a novice can be assisted to become an expert. For teaching and learning we need to capture not only the associations the expert makes, but why and how these associations come to mind.

Hierarchical Organisation (Novak, 1988): advocates the storage of concepts and relationships by the decomposition of larger units into manageable blocks. These are hierarchically organised into structured levels

In all the models, learning is generally seen as conceptual change. It is basically the way in which this conceptual change should be brought about that educators have different opinions on. The learning theories and models discussed are usually consciously or subconsciously employed in situations within which teaching and learning is purported to take place. For this to happen, environments should be created such that the system may be transformed from an initial state to a final state where it can now perform. We shall refer to all such situations where we try to propagate and induce learning in some way as learning environments. Those commonly employed may be classified as transmission, interactive discussion, problem-solving and student-initiated. The learning environment for each of the cases may be simply an individual student interacting with texts, with a machine tutor or with a live teacher; may be between a live teacher and student(s); or may be between students. The 4 learning environments against which the 30 systems have been reviewed are briefly described below.

Transmission

In a transmission learning environment instruction is delivered by one individual to another or to a group. Learning is hierarchically organised by decomposing the main component into sub-components. It is assumed that one can make a student learn by telling the student what is correct and incorrect. The learner is usually assumed to be like an 'empty bucket' into which knowledge is to be poured. In many cases the learners have to internally transform the knowledge received and integrate it with their existing knowledge for usage. They are usually left to make the expected links as the teacher cannot cover all the possibilities.

Interactive Discussions

Interactive discussions here means discussions involving teacher-student, machine-student and student-student. Interactions are well suited for relevant feedback to occur. Through interactive question-answer sessions a profile of the student's understanding and deep seated apprehensions or misapprehensions may be constructed and corrective measures implemented (Webb, 1988). Examples and counter examples can easily be introduced to challenge, correct and clarify student concepts and explanations provided through sharing of various viewpoints.

Problem-Solving

A problem-solving learning environment assumes that chances of learning are enhanced in applied or contextual settings. The student is provided with the opportunity and assistance to apply the correct principles. Appropriate examples and problems need to be selected to ensure directional movement towards complexity in conceptual attainment. Problems can be graded from the 'cook book, type of simple textbook problems requiring the application of an elementary concept, to general design type questions requiring a complex conglomeration of inter-related concepts. As more problems are solved on the application of a concept, the concept is incrementally refined (Michalski, 1986).

Student-Initiated

The student makes learning decisions on how to sequence the subject matter for learning and is seen as a processor of experience and information to bring about conceptual change. The learning situation is seen as a program of activities (ideally initiated by the student) to uncover the conceptions of students and to build on them. To construct meanings effectively pupils have to be taught to ask questions of themselves, of each other and of teachers and other adults (Biddulph & Osborne, 1982). The learner will then be able to inquire, discover and organise the experiences presented to develop some meaningful cognitive structures.

ICAI: INHERENT LEARNING THEORIES

Thirty intelligent computer-assisted instructional (ICAI) systems have been reviewed (Singh, 1992) to determine the learning theories and environments upon which they are based (see Table 2). None of the systems make explicit mention of the learning theories used. Those which use the interactive discussion environment do make explicit mention of the Socratic style of question and answer type of dialogue sessions implemented. In practice a combination of learning environments are employed. The difference between settings is the degree to which each comes into play. From Table 2 it can be noted that the transmission and problem-solving environments are the most extensively used in many systems. The number of systems which are extremely transmission and problem-solving oriented are 9 and 7 respectively. Only 3 systems use interactive discussion in the main and there are none which predominantly espouse the student-initiated environment.

Of the 30 systems reviewed, 21 espouse graded skill development and discovery in stages using hierarchical based theories to some extent or other (table 1) . This propagates an image of teaching and learning as highly stage structured and leading stepwise from one phase to another. This is understandably due to the state of the art of computer technology whereby everything is structured using production rules, frames, semantic nets or formal logic. As such, computers are to date only capable of handling information which has been pre-programmed in structured form. Furthermore, most of the systems use the transmission and problem-solving environments. These limit learners' reflection on their ideas. In these environments learners are given information and led stepwise to the goal or problem solution. Even then, much of the instructional material omits information that the student needs to know in order to perform the tasks and the student is left to figure them out by trial and error experimentation. An interactive learning environment is required which clarifies the ideas of students so that connections may be made.

TABLE 2
LEARNING THEORIES AND LEARNING ENVIRONMENTS ON WHICH THE COMPUTER-ASSISTED INSTRUCTIONAL SYSTEMS ARE BASED

	Systems	Learning Theories (Groups are given in table 1)								Learning Environments			
		A	B	C	D	E	F	G	H	T	ID	PS	SI
1	Scholar	M	P							M	P		
2	Excheck		P	M						P	S	M	
3	Sophie			S	M			S			P	P	S
4	Isaac						S			P			
5	Newton		M				S					P	
6	Buggy					S						M	S
7	Bacon.5		M		M							P	
8	Mecho		M									P	
9	West			S	M		S			S	S		
10	Why		M		M					S	P		
11	Wumpus						S					M	
12	Able						M					P	
13	ACE					S						P	
14	Integrate		M			S				M		S	
15	Quadratic				S						S		
16	LMS		M							M		S	
17	Macsyma		P						S	P			
18	Spade								M		S	M	
19	Spirit		P						S	P	M		
20	DMS							S	S	P			
21	Guidon		M							S	M	P	
22	Proust			M						P		S	
23	Gaslab				P							M	
24	GEO				P	S				S	M		M
25	Stella							S	S	P			
26	Mendel				M	S				S	S	M	M
27	ACT/PUPs		M				M			M	S		
28	Kangasauras							S		P			
29	Quest		M		M		M			S	S	M	S
30	Mathematica								S	P			

T: Transmission ID: Interactive Discussion PS: Problem Solving SI: Student Initiated S: Used slightly M: Used to a medium level P: Used predominantly

Intelligent computer-assisted instructional environments have been used as teaching tools as well as to supplement student learning. They provide individualised sessions for the students. Therefore ICAI environments should encourage and be based as much as possible on the student-initiated model. The core of our discussion in the ensuing section is to highlight the general program features required for a student-initiated learning environment to be realised.

PROGRAM FEATURES FOR A STUDENT-INITIATED ICAI

A student-initiated learning environment takes into account the constructivist model of learning whereby the learner is seen as an active participant in the process. The knowledge which learners bring with them to the learning situation and the active construction of meaning which goes on constantly while individuals interact with the environment are seen as important factors which need to be considered. Learning is seen as the way the mind organises reality through a combination of experience and information. In this form of learning environment, conceptual change is brought about by the student. The student makes decisions on learning (e.g. the sequence in which to learn the subject matter, and when to learn any particular topic). With these in mind, the essential features an ICAI system needs to have to function as a student-initiated learning environment are:

1. A facility enabling the student to be an active participant in the learning process, thereby controlling the direction and pace of learning, preferably at all times.
2. The system must be like a knowledgeable teacher, aware of the pitfalls for students in their learning experience. It must have a working knowledge of the prior conceptions of students and the assumptions they tend to make in the learning and problem-solving process. This awareness and knowledge will enable the system to help the students.
3. Through interaction the system should be able to compile and determine the knowledge level and problem-solving awareness of the student. Research has shown that this is an important factor influencing learning. Some systems already use an overlay model (Goldstein, 1982) where the student's performance is compared to the expert's, or a buggy model (Brown & Burton, 1975) where the points at which the student's performance differs from the expert's are noted to obtain a student knowledge profile.
4. The system must enable the student to make learning decisions and handle alternative modes of operation dependent on student needs. Students should be able to choose the preferred style of learning e.g. by being given hints, by discussing their proposed solution to determine when help is required, by using analogy, or by the type of explanation required. The student might wish to use the system for various learning purposes e.g. simply to clarify ideas, to have a discussion on a particular aspect of the problem, to obtain help in solving a problem, to test whether an analogy is applicable, or to be assisted to make a graphical or diagrammatic simulation. Feedback given must be designed such that it forces the student to think.
5. There should be provision for the student to apply the ideas developed for consolidation and reinforcement. The system needs to provide a range of models, experiences, demonstrations, worked examples and analogies to test out acquired ideas or concepts.

6. The system must be able to challenge and discuss ideas which will help the student to deal with contradictory previous knowledge. This will help students to discard, modify or integrate prior knowledge with new situations. Merely explaining away an inadequate conception is not sufficient. To do this the system has to be supportive, cooperative, committed and interested in the student's knowledge. For the system to be effective it must seen to be encouraging. It should try to ensure that students who genuinely make an effort meet with some form of success.
7. While interacting the system should be able to make explicit the links to other topics within the subject as well as links to knowledge within the particular topic. Students are rarely made aware of these connections within the subject domain. Knowing such connections will enable the students to develop connections between their schemata and in turn enhance the possibility of coalescing them into larger functional schema units.

EXTENT TO WHICH A STUDENT-INITIATED ICAI SYSTEM MAY BE REALISED

To realise a system propagating a student-initiated learning environment we need to look at the mechanics of such a system within an actual classroom situation. The students work on a task that they are self motivated with and whenever they encounter problem areas they would seek more information. To perform the task the students need a certain basic working knowledge of subject matter, and avenues for seeking further information. Furthermore, they have options of consulting someone better versed in the domain to discuss ideas, or to discuss amongst themselves. Students can choose how to learn. They can ask the teacher to give an example, provide an analogy, or simply provide diagrammatic or graphical depiction to clarify the problem.

One problem with this ideal situation is to recognise when student conceptions are not in line with the principles governing the structure of the domain. Once the conceptions are known, the system can be used to challenge the student with counter examples or alternative applications and explanations. Initially therefore, the system could be programmed with alternative conceptions known to commonly exist amongst students. Over time, it can be used to collect data on alternative conceptions. Not only will this make the system dynamically evolving but will also bring it closer in similarity to the performance of a live teacher working within a student-initiated environment. A live teacher takes years to accumulate a repertoire of skills and information to handle students' conceptions and errors. The teacher develops a variety of techniques to deal with the common conceptions and errors. There are situations in which the teacher is astounded or baffled. For these reasons, we should not expect the system to deal immediately with all errors and conceptions.

It is impractical to expect a system to be able to solve the difficulties outlined above. A good teacher provides information and suggests avenues for students to move towards solutions to tasks. An ICAI system should provide activities with the same intentions. For a system to function in the manner described above dialogue is essential. To overcome this, pull down menus may be used to access key and common words necessary for communication and interaction between the student and the system. Words may be individually chosen through the menu to form sentences. The menu can also provide choice of algebraic constants, combination of numbers, functions and mathematical operators for representing quantities and for forming equations.

Necessary feedback could come through the system rephrasing or reiterating for confirmation the students' input. This is one area with which the state of the art of computer technology is still grappling. However this difficulty may be less extreme when working with limited dialogue within a restricted subject domain.

CONCLUDING REMARKS

We have identified the central features required for a student-initiated intelligent computer-assisted environment. The problem areas of recognising errors and conceptions and providing natural language interaction have been discussed. Although we understand that creating a system with the depth and breadth of a human tutor is presently not within the current state of the art, we have commenced a research project working towards this goal. We intend the system to act as a data collector which may be constantly upgraded particularly in the early interaction with students. To overcome the natural language problem we advocate interaction through pull down menus.

The degree to which this system will be successful clearly depends on the variety of students' interactions with it. We might not be able to totally and ideally implement a student-initiated environment incorporating the constructivist model. We hope however that this research will provide a major step towards realising such a system.

REFERENCES

Ausubel, D. P. (1968). Educational psychology: A cognitive view. New York: Holt, Rinehart and Winston.

Biddulph, F. & Osborne, R. (1982). Some issues relating to children's questions and explanations. Working Paper No. 106, SERU, University of Waikato.

Bigge, M. L. (1982). Learning theories for teachers. New York: Harper and Row.

Brown, J. S. & Burton, R. R. (1975). Multiple representations of knowledge for tutorial reasoning. In D. G. Bobrow & A. Collins (eds.) Representation and understanding: Studies in cognitive science. New York: Academic Press.

Bruner, J. (1985). Models of the learner. Educational Researcher, 14 (6), 5-8.

Coombs, A. W. & Snygg, D. (1959). Individual behaviour. (revised edn.) New York: Harper and Row.

Driver, R. & Oldham, V. (1986). A constructivist approach to curriculum development in science. Studies in Science Education, 13, 105-122.

Gagne, R. M. (1977). The conditions of learning. New York: Holt, Rinehart & Winston.

Goldstein, I. P. (1982). The genetic graph: A representation for the evolution of procedural knowledge. In D. Sleeman & J. S. Brown (eds.) Intelligent tutoring systems. New York: Academic Press.

Kelly, G. A. (1955). The psychology of personal constructs. New York: Norton.

Maslow, A. H. (1987). Motivation and personality. New York: Harper and Row (3rd edition).

Michalski, R. S. (1986) A theory and methodology of inductive learning. In R. S. Michalski, J. G. Carbonell & T. M. Mitchell (eds.) Machine learning: An artificial intelligence approach. California: Tioga Publishing.

Novak, J. D. (1988). Learning science and the science of learning. Studies in Science Education, 15, 77-101.

Pinard, A. & Laurendeau, M. (1969). Stage in Piaget's cognitive-developmental theory: Exegesis of a concept. In D. Elkind & J. H. Flavell (eds) Studies in cognitive development: Essays in honor of Jean Piaget. New York: Oxford University Press.

Rumelhart, D. E. & Norman, D. A. (1981). Analogical processes in learning. In J. R. Anderson (ed.) Cognitive skills and their acquisition. New Jersey: Lawrence Erlbaum.

Singh, A. (1992). Computer based learning environments. Unpublished paper, CSMER, University of Waikato.

Skinner, B. F. (1969). Contingencies of reinforcement. New York: Appleton-Century-Crofts.

Thorndike, E.L. (1949) Selected writings from a connectionist's psychology. New York: Appleton-Century-Crofts.

Webb, G. I. (1988). A knowledge-based approach to computer-aided learning. International Journal of Man-Machine Studies, 29(3), 257-285.

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ATTITUDES OF PRE-SERVICE MATURE AGE WOMEN STUDENTS TOWARDS TEACHING PRIMARY SCIENCE: AN INTERVIEW STUDY.

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ABSTRACT

During the first semester of their teacher education degree mature age women improved significantly in their attitude towards teaching primary science compared to other sub-groups. The reasons for this difference were explored by interviewing several of the mature age women. An interpretation of these interviews and possible implications for pre-service science education are reported.

INTRODUCTION

In an earlier study (Skamp, 1989) the attitude towards teaching primary science (ATTPS) of pre-service teacher education students on entry into their Bachelor of Education (Stage I) degree and at the end of their first semester, which included a compulsory science curriculum studies unit, was reported. The ATTPS scale devised by Moore (1973) was used. Analysis of the data revealed that although all students improved significantly in their attitude towards teaching primary science, mature age women scored 8 to 11 points higher than all other subgroups (male and female school leavers, and male mature age students). In order to try to ascertain why they had more positive attitudes towards teaching primary science than other sub-groups in the sample a number of these mature age women were interviewed. Appleton (1991) has reported, via survey analyses, on the perceptions and attitudes of mature age pre-service primary teachers compared to school leavers, but this would appear to be the first study to explore the reasons for mature age pre-service primary student's (here females) attitudes towards science teaching.

White's (1988, p.101) definition of 'attitude' guided the plan of this study: an "attitude to a concept such as science is the person's collection of beliefs about it, and episodes that are associated with it, that are linked with emotional experiences". He goes on to say that "...to change an attitude involves adding new propositions, images, strings, and episodes, and abandoning old ones" (p.108). The interviews therefore attempted to identify particular 'images, episodes and propositions' that may have explained initial attitudes, and then whether additional 'images, episodes and propositions' had been 'taken on board' or others abandoned that could 'explain' the attitude changes identified in the earlier study. Further the mature age women were asked for their perceptions of the reasons for the observed attitude differences between themselves, school leavers and mature age men.

PROCEDURE

Sixteen mature age females completed the ATTPS questionnaire on entry and at the end of semester 1 (Skamp, 1989, p.262). By semester 5, when the interviews were conducted, five of these 16 were no longer enrolled in the program, and three could not be identified from the questionnaire data. Of the remaining eight, seven were interviewed. Further investigation revealed that there were five other mature age women still enrolled in the program (in semester 5), who had completed the ATTPS scale either on entry or at the end of semester 1. Three of these women were also interviewed. (The small sample size is a limitation of the study but does not invalidate the range of proposed 'explanations'.) Table 1 summarises the qualifications and background experiences of the sample. Emma and Jane had initially entered pre-service teacher education as school leavers and later as mature age students. Their 'stories' offer support for the perceived differences proffered by interviewees between mature age women and school leavers.

TABLE 1
ATTPS SCORES, QUALIFICATIONS AND
BACKGROUND EXPERIENCES OF THE INTERVIEWEES.

STUDENT	ATTPS SCORES[1]			HIGHEST LEVEL of SCHOOL SCIENCE[2]	WORK/LIFE EXPERIENCES SINCE SCHOOL[3,4]
	ON ENTRY	END SEMESTER 1	DURING SEMESTER 5		
Ann	40	-	70.5	Yr 11 Biology	Office work(7 yrs); Mother
Beryl	46	62	70	HSC Biology	Trained Nurse; some nanny work;clothing factory helper
Carol	-	63	69	SC Science	Retail industry; nurse training (1 yr);mother
Denise	43	60.5	68	None	Receptionist through to Conference manager; mother
Emma	47	49	68	SC (Biology?)	Travelled;casual jobs;artwork
Fiona	49	68	68	Yr 11 Physics & Chemistry	Incomplete BA; travelled;office work;mother
Gayle	42	66	67	Yr 9 science (left school at 15)	Childcare TAFE course;Childcare(5 yrs)
Hanna	51	77	67	HSC 3rd level Science	Worked for Government Departments/Private Industry;farmer;mother
Ingrid	46	62	58	SC Science	General store attendant; air hostess;taught craft(primary children);managed craftshop
Jane	50	-	50	HSC General Science	Secretarial;Director's assistant at pre-school

1. Possible range 0 to 90.
2. Yr=year; HSC=Higher School Certificate (Yr 12) SC=School Certificate (Yr 10)
3. Ann, Beryl and Hanna felt some of their work was science related.
4. Emma and Jane initially entered tertiary education as school leavers. These are their experiences since leaving Teachers' College or University and their entry as a Mature Age Student.

All interviewees were asked the same questions with very minor variations (for full details, see Skamp, 1992). Each interview lasted about 30 minutes. After initially seeking the general and scientific school and post-school experiences and qualifications of the sample, reasons for entering teaching as a profession, approaches to study and thoughts about one's role as a teacher (on entry into the University) were sought. Perceived differences to school leavers were requested as it was thought these may partially explain differences in attitudes towards teaching primary science. Later questions specifically explored recollections of attitudes about teaching science on entry into University and reasons for these feelings. Interviewees were then told their attitude scores on completion of the first semester and asked how they would explain this change (or, in one case, lack of change). At this stage the results relating to firstly, school leavers, and secondly, mature age men, were shown, and the mature age women were asked if they could offer any reasons for the differences. The final questions related to the scores the interviewees obtained when they completed the ATTPS scale again in Semester 5. They were asked for any further explanations that they could give relating to their Semester 5 score. The focus in this paper is on the reasons for change in the mature age women at the end of Semester 1, and the perceived differences to school leavers. For other interview results see Skamp (1992).

ATTITUDES TOWARDS TEACHING PRIMARY SCIENCE

ATTPS scores can range from 0 to 90 with a high score meaning a more positive attitude. Table 1 shows that all interviewees entered University with low scores (similar to other cohorts), but showed marked improvement in attitudes after completing the first semester (except for Emma and probably Jane). These scores were generally maintained or improved by Semester 5 (except for Jane). Appleton (1991, p.5) found a similar result when his sample was surveyed at the commencement of Semester 2 (after completing a practicum, but prior to the first science curriculum unit). These results may mean that there are general reasons for the attitude differences between school leavers and mature age applicants. The early questions in the interview explored this hypothesis, but are not reported here (see Skamp, 1992).

COMMENCING ATTITUDES TOWARDS TEACHING PRIMARY SCIENCE

The ATTPS scale indicated that the mature age women had negative to neutral attitudes on entry. Interview responses related to these scores indicated that the sample fell into three categories: those who lacked confidence to teach primary science; those who had an 'open' or 'determined' mind about teaching primary science, and Beryl who had no fears on entry. The reasons given by Ann, Carol, Emma, Gayle, Hanna and Jane, who belonged to the first grouping, included: the non-appealing nature of secondary school experiences (which they transferred to primary science); their lack of science understanding/ background; the 'closed' and 'non-individual' style of secondary science teaching; the apparent gender bias (in schools and in society) towards males; and perceptions of self (for example, as being "more into creative arts"). Denise, Fiona and Ingrid, and to some extent Gayle, who had an 'open' or a 'determined mind' about teaching primary science, were positive about their ability to teach primary science (even if there were some underlying concerns). They were positive because of the confidence gained by past achievements; some positive recollections of science teachers; and the enjoyable nature of some secondary science classes (detailed in Skamp, 1992).

ATTITUDES CHANGES AT THE END OF FIRST SEMESTER

Of the ten mature age women, seven had markedly improved their ATTPS scores by the end of semester one. The 'explanations' for the positive change in attitudes appeared to focus around: changed perceptions of teaching, learning and the curriculum in the primary school; the characteristics of the university science unit (structure, activities, assessment) and the lecturer; and outside influences (peer work groups and interaction with children). These results can be compared with similar findings for female primary and early childhood teachers who completed a semester length inservice program (Kirkwood, Bearlin & Hardy, 1989).

Changed perceptions of the nature of primary science. Four interviewees found the nature of primary science differed significantly from previous expectations. The science curriculum unit just opened up a "whole new world of investigation... it was much broader and that's what delighted me" (Fiona), or as Gayle said "now I know what it's about, it really wasn't what I thought it was about ... and it's not so frightening now after all" (Beryl made similar comments). Sometimes the changes related to specific aspects of the nature of science. Carol generalised that it was the "process, what happens along the way" which was an important proposition that influenced her thinking. It related to the way children investigated, but was important for her too:

> I mean it was great when we were confronted with a problem to actually work through, and get what you called the right answer at the end. But it was all the processes that you went through along the way that I came to terms with and I realised were 'really important for children too, that they could identify them, and later on use those same steps when they confronted some other sort of problem... I think I had always been taught that science was...here was your problem, find the answer, there's only one real answer to it and that's it. Anything on either side is just not on. And I think I had to really re-think that whole issue.

As Gayle reflected, her practical (University) sessions helped her "pick up the idea that there wasn't always a right and wrong answer, and that there was room there to practise things and just to find your own way, and come to your own conclusions. And you didn't always feel as though you had to try and find, look for some answer (the lecturer) wanted". For Fiona the content of the primary curriculum was also a positive determinant: it related to "life and everything..not just this chemistry, physics line with very traditional equipment".

Revised perceptions of the role of primary children. Beryl, Denise and Ingrid had not thought that the children would be doing so much. As Ingrid said "...and I could see how great that would be if the children were actually doing it, cause I'd sought of try and put myself in the children's position and could see that wow, wouldn't kids love to be actually getting their hands on this, and actually doing it...". The University science curriculum unit helped at least one of the above to see the possibilities for children. "(The lecturer) made ...(us) do what children had to do. And we were finding it quite fun and quite interesting. We would predict what was going to happen and quite often it was nothing like what happened, and we were adults ... and what with children ... I could see that that would really interest them".

View of the role of the primary teacher changed. The view that the teacher does not have to have a command of a wide range of scientific knowledge was a relief for several interviewees. Gayle expressed it very succinctly:

> Well I can see now that it's not so much that I have to have, be full of all this knowledge that I have to share with the kids. It's rather more that I have to be able to direct them to learn for themselves, and that I can learn with them.

> I don't have to necessarily have to have it all up here mentally. But I can learn things with them as we go along, whereas when I started, I guess I just thought that I had to be able to share all this knowledge that I didn't have.

Hanna felt similarly, but Fiona expanded her ideas more forcefully. For her the image of finding out with the children was very powerful. The "feeling that I can be there, so much part of it with them, it's the togetherness of it, that really did turn me on."

Ability to cope with the Science curriculum unit's content. Gayle and Ingrid felt that an important factor for them was the realisation that they were coping with the content. Interactions with, and encouragement by, the lecturer, and doing well in assignments were influential factors:

> But certainly just the sort of comments (the lecturer) made and the way (the lecturer) spent time, with both ... and myself, 'cause we were both in the same situation. That (the lecturer's) attitude towards us and spending time with us, really helped both of us through (Gayle).

Good grades reinforced these women's emerging view of primary science:

> ...at first I had no idea what it was about. Then as the semester went on, I understood it more, and was getting, like reasonable marks. During the semester I thought well, what I'm perceiving science to be, must be you know, reasonably on track, or I wouldn't be doing OK.

Hanna saw an assignment which had an environmental emphasis as possibly the "turning point in her perception of science...It was my only distinction!" and "I thought well it was easy you know. It wasn't such a hassle after all". The assignment had an environmental emphasis.

Characteristics of the lecturer. "I think first of all, it had a lot to do with the lecturer we had". He used an "approach of making things uncomplicated and unthreatening (and this helped) me to relax, and become ready to come to terms with an area that I hadn't ever been able to come to terms with" (Carol). Fiona immediately responded to why her attitudes had changed by saying her lecturer's "teaching", adding that he "certainly made it seem very much more within my grasp".

Other characteristics of the University science curriculum unit. The realisation that the unit was "teaching us to teach science" not "teaching us science" seemed to remove some of the fear for Hanna. Two other features of the unit which seemed to contribute positively to an improved attitude towards teaching primary science were: the clear organisation and expectations of the unit and the chance to do experiments in an atmosphere that encouraged understanding of the ideas and the processes:

> ...so I was allowed to relax and think well, if I can work through this and understand what I'm doing, and I'm allowed to make mistakes...then I can do this with children too (Carol).

Interactions with children. "Experimenting with (her own) children and getting their ideas" was very influential for Denise. She did this partly as a consequence of her own initiative, and partly because it was an optional assessment requirement. The enthusiasm with which her children attempted the investigations, and "how minimal the input had to be" impressed her:

> I put a lot of it (i.e. her change in attitude) on to that, the enthusiasm that was shown by the kids as by just showing them an interesting little experiment or whatever.

Working with a peer or peers in outside groups. Carol's confidence was helped by working in groups in which she found others had the same "problems, fears, and doubts", and so she did not have to work through these by herself. Beryl was almost going to withdraw from the unit, but a close friend said "don't you dare, ... we'll get on to it on Friday night and the weekend, we'll do science". This appeared to be a critical incident for Beryl who added later in the interview, "I think I became more confident in that once I started to understand it more, I enjoyed (it)".

NO APPARENT ATTITUDE CHANGE AT THE END OF THE FIRST SEMESTER

Emma and Jane's ATTPS scores did not change initially (see Table 1). For Emma this may have been due to personal reasons but she also added that she was "overwhelmed by it all", and "science in particular tended to confuse me a bit more I guess". Certain images, which were positive for some (see previous section) were negative for Emma. She felt that she "couldn't quite get her head around mass and weights and volts and electrical currents...I liked the processes but ... I still felt like I didn't know anything, like enough about the real facts of science...". Emma considered her limited high school science and the "maths (which she wasn't 'very good at') behind all those things" may have been responsible. Jane's (semester 5) ATTPS score initially surprised her, but on reflection she made comments that suggested there were still difficulties for her. She said she "didn't dislike science", but did add that during her last Practicum she had difficulty figuring out how to start teaching science. Further probing revealed that there were still some real stumbling blocks for her: "we did batteries and the lights and that's completely beyond me", and added that she learns things and they "stay for a little while, but then it goes". She also felt that the: "...terminology puts me off a bit...really scares me a little bit with variables and I'm still not confident in saying I know what an independent one is and a dependent variable is...there's process skills and what's the other?". Jane has difficulty with some of the conceptual understandings in science, which affects her confidence. However on a positive note she concluded "before I had no interest, now I do have an interest, ... (and I feel) it's up to me really" . A further motivation for her was that she stated that her "main reward" had been to see "how the kids think and how they investigate".

MATURE AGE WOMEN'S PERCEPTIONS OF WHY THEIR ATTITUDES WERE MORE POSITIVE THAN SCHOOL LEAVERS

These women shared first semester experiences with school leavers and their perceptions are categorised as 'barriers' that may have limited the improvement of the attitudes of school leavers towards teaching primary science:

The barrier of secondary school science. Denise reflected on her secondary child's current science experiences. Her daughter had not experienced "dabbling and just getting in and experimenting without being judged on what they're doing all the time".

Denise felt her daughter's secondary science experiences were "just blocking anything she's going to (do)...". Consequently Denise argued that some school leavers may feel similarly and first semester at University may not be long enough to overcome such perceptions. Beryl, Carol, and Fiona held related views. For example Beryl said:

> Maybe (school leavers) still have negative attitudes from science at school...where(as) mature age students have been separated for so long, that they're sort of looking at things more objectively, more as a new situation, rather than continuation of a past thing.

Secondary science experiences may have also developed a "blase" attitude among some school leavers who may have felt "I can teach this, yeah, no problem, whereas I came in thinking, oh science!" (Hanna)

The lack of realisation of the role of primary science in a child's education. "I don't think they (school leavers) attach very much importance to science as having any terribly important effect on children at all, as mature age students do" - they do not see the "broader effect" of primary science (Carol). Ann thought that "(school leavers) don't see the importance of what they can do with the material they're learning" and added :

> ...and I think they (school leavers) fail to see why it's (science) so important ... having had a few more years experience they would realise that yes...science is part of everything in the world and so is technology and maths is used...they would see it's more crucial to the state of the world, for people to build more expansive concepts and knowledge about science... and that's probably why my attitude changed.

Denise came to a similar conclusion, based upon the positive science experiences of her primary age son, and the less positive experiences of her secondary age daughter. Appleton (1991, p.5) also identified the "perceived importance of science and technology to an overall education" as a "main issue" that separated mature age students from school leavers.

Gender(?) factors: Encouragement and environmental emphases not appreciated. Ann and Carol developed these two factors:

> Women are I feel more intuitive than men, very curious. And if allowed to be encouraged in a certain area, that they feel they weren't encouraged in, will really make a really big advance in it. Especially if they see that it has some benefit for our future and for the environment- I think women are really attuned to the environment and feel a very deep concern for it. And science is really taking that sort of lean now towards environmental awareness (Carol).
>
> They (school leavers) get the material and say this is for teaching science. But they don't see this is not only for teaching science, this is about changing our attitudes towards the environment, towards women, towards technology, towards this, towards that. All the things that are really important if the planet's going to survive. (Ann).

Appleton (1991, p. 6) also concluded that "mature age students are more interested in teaching obvious environment based areas of science (life and earth)".

Differential practicum experiences. Beryl related how she had seen supervising teachers in school "in quite a few cases" provide more opportunities for the mature age students (student teachers often worked in pairs during the Practicum in semester 1) because the teachers "treat you like you know a bit more than the younger ones". The implication here is that the older students would therefore grow in teaching confidence more readily.

Other reasons given were: lack of determination among school leavers (they "really didn't care too much", whereas the mature age women were task oriented, often due to the experiences they had had prior to University (Ingrid, but also supported by Ann); the teaching approach may have been more suited to older learners (Fiona speculated: "There's something about the way (the lecturer) was doing it, his enthusiasm, they (school leavers) almost got turned off by it I think. Cause they thought he couldn't be for real being so enthusiastic about his subject ... but we (older students) loved it, because we liked that enthusiasm"); inability (of school leavers) to cope with University-Practicum differences (Beryl reported that she had heard comments from school leavers that "what we learn at Uni is not in reality, on prac" and "people are not confident in teaching the way we learn here, because we haven't practised it on prac". She felt that mature age females, many of whom are mothers, already more familiar with children than school leavers, would be more willing to try different approaches in schools and consequently experience success); and an inability to see the University science curriculum unit's structure (Gayle felt that "the links were there all the way through the semester...it just seemed to follow in such a logical order", but for "some of them (school leavers), they just didn't seem to see much sense in what was going on and they didn't seem very interested anyway").

In summary four of the reasons for perceived cohort differences at the end of Semester 1 relate to the science curriculum and practicum units. Secondary science experiences, personal attributes of some students, and a greater appreciation of the role of primary science (and its environmental associations) also figure prominently. Several of these reasons align with the identified features of the learner-centred (and to a lesser extent, the knowledge- and person-centered) models of exemplary practice among pre- and in-service primary science courses which Bearlin (1990) found produced positive attitude changes in female students.

AN INTERPRETATION AND IMPLICATIONS

White (1988. p.108) speculates that experience and social transmission are key determinants in the formation of attitudes, and concludes that "direct experience" is a more powerful influence in the formation of students' attitudes to science than "socially induced beliefs" (eg., the media), while not underestimating the latter. Strings (sequences of words or symbols), he believes are not as important as images (eg., stereotypes of scientists) in the development of attitudes to science. Images are probably most often acquired through social transmission, although a dramatic event or many similar events could lead to the same result. Attitudes may form at an early age, and over a long period, but be changed by a single experience. These views about the formation of attitudes are a useful framework in which to interpret the interview responses.

These interviewees' somewhat negative attitudes on entry were partly based on negative episodes related to cumulative secondary science experiences, eg., science as chemistry symbols. Selected images, such as the perception that only males can succeed at science, were probably also influenced by social transmission (sometimes backed by experiences). However for some interviewees the general attitude of desiring to succeed (e.g. at teaching), seemingly based on positive episodes of being successful in other life experiences, appeared to override or at least balance these concerns about teaching primary science. Also for some there was a smattering of positive science episodes which were remembered and therefore helped some mature age women see teaching science in a more open way.

For those who changed their attitudes the influence of new propositions about science teaching seemed important for most. Social transmission also appeared to play a role, but related direct experiences (trying out such propositions in practice, eg., with one's own children) further reinforced the change. The "right answer" syndrome, and the style of teaching associated with it, mentioned by several women is an example of a proposition change, that seems to fulfil these conditions. The old proposition was replaced.

Pleasurable episodes were obviously important for some, eg., supportive feedback and a relaxed learning atmosphere in the university unit. For others there is also evidence of the power of a single episode, eg., a successful assignment was for one a possible 'turning point'; for another getting together with a friend to study science over a weekend. Also for a few women the positive influence of gender and environmental issues was important. Social transmission was probably a significant factor in these cases.

This interpretation suggests that attitude change can be influenced by the nature of pre-service units, but that external factors also appear to be important. The message seems to be that a range of reasons are responsible for the observed attitude changes and the explanation is not simple. However the power of a single (positive or negative) episode should not be overlooked.

These women identified characteristics of the science unit which would be considered to be consistent with effective practice. Why did they not affect the school leavers to the same degree? It may be that school leavers' ability to appreciate differences between secondary and primary school science may simply take time. Time may be required to: have sufficient positive episodes to move over the barrier of negative secondary science experiences; become socialised into the world of the primary child and the primary curriculum (partly via cumulative episodes with children during practicum); and, become more aware of contexts in which primary science, gender and environmental issues are important. As there is some evidence to suggest that school leavers' attitudes do 'catch up' towards the end of their degree (Skamp, 1992), then a possible implication of this interpretation is that science curriculum units commence in the second or later semester in teacher education programs.

It should be emphasised that this study has focussed on the reasons for the *difference* in attitudes of mature age women compared to school leavers. The causes of the differences *per se* have been highlighted in terms of White's (1988) views. These 'causes' reflect several important issues raised in the gender and science education literature (see Bearlin, 1990, and references therein), which deserve further analysis in terms of why the female school leavers were not similarly affected. Space precludes their inclusion here.

In conclusion this study indicates that attitudes towards teaching primary science are influenced by a number of factors, which could be interpreted as propositions, events, and images, and which are subject to change. The causes of the change may be many. Further they could be cumulative, or one off events. That some school leavers were not influenced as much as mature age women in the sample investigated here has tended to suggest that the change may be slowed down for some of this sub-group because of the recency of some negative experiences, and lack of exposure to other positive experiences. The data suggest that for some school leavers there may be no 'quick fix' solutions to developing more positive attitudes to teaching primary science.

REFERENCES

Appleton, K. (1991). Mature age students: how are they different. *Research in Science Education*, *21*, 1-9.

Bearlin, M. (1990). Towards a gender sensitive model of science teacher education for women primary and early childhood teachers. *Research in Science Education*, *20*, 21-30.

Kirkwood, V. Bearlin, M. & Hardy, T. (1989). New approaches to the inservice education in science and technology of primary and early childhood teachers. *Research in Science education*, *19*, 174-186.

Moore, R.W. (1973). The development, field test and validation of scales to assess teachers' attitudes towards teaching elementary school science. *Science Education*, *57*, (3), 271-278.

Skamp, K. (1989). General science knowledge and attitudes towards teaching science and science teaching of pre-service primary teachers: implications for pre-service units. *Research in Science Education*, *19*, 257-267.

Skamp, K. (1992). Attitudes of pre-service mature age women students towards teaching primary science: an interview study. Paper presented at the Australasian Science Education Research Association Conference, University of Waikato, Hamilton, New Zealand, July 10-12, 33pp.

White, R.T. (1988). *Learning science*. Oxford: Blackwell.

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DETECTION OF MISSING AND IRRELEVANT INFORMATION WITHIN PAPER AND PENCIL PHYSICS PROBLEMS

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ABSTRACT

Secondary 5 students from four schools in Hong Kong were required to classify 18 paper and pencil physics problems in terms of whether the problems contain necessary and sufficient, missing or irrelevant information for their solution. Students' ability to denote missing information correlated rather highly with the solution rates of the problems. In another test, students were asked to classify whether the problems in each of six pairs were similar to or different from each other according to students' self-determined criteria. Students who used a deep structure (i.e. used the underlying physics principles) to classify the problems have significantly higher scores in detecting missing and irrelevant information and in the solution rates than those who used surface structure or features for classification. It is argued that a student who is able to identify what information is sufficient, missing or irrelevant for solving a problem understands the problem structure and so is better able to solve it. Such a student is likely to adopt a deep structure in categorizing physics problems. This latter result corroborates with the findings of the expert-novice research paradigm.

INTRODUCTION

Human problem solving has been a major area of research in cognitive science. Initially, researchers studied how people solved puzzles where the amount of knowledge needed to understand the problems was minimal. Later studies focused on problem solving in semantically rich domains such as algebra, physics and computer programming. Problem solving in these domains requires a great deal of specific knowledge and depends on agreed logical principles. Concomitant with such research activities, there is an increasing recognition over the past decade that problem solving is an important aspect of science education, both as a means to facilitate learning and as an exercise to acquire problem solving skills.

There are two research strands in problem solving in semantically rich domains. One strand pays attention mainly to the process of solution whilst the other focuses on the knowledge of the problem solver and the organization of that knowledge. Within the latter strand, Mayer (1983, 1985) proposes that to solve algebraic word problems five categories of knowledge are needed: linguistic (knowledge of the language); semantic (knowledge of facts about the world); schematic (knowledge of problem type and structure); strategic (how to develop and monitor a solution plan); and algorithmic (how to perform a given sequence of operations).

Low and Over (1989) required Year 10 students to classify algebraic word problems in terms of whether they contained missing or irrelevant information for solution. They found that performance on this task (called text-editing) correlated very highly with the solution rates for the problems and with the ability to determine whether algebraic problems were similar to or different from each other. These findings led Low and Over to conclude that text-editing is a measure of schematic knowledge.

The present study is, to some extent, a replication of Low and Over's study but in a different domain, viz. physics problems. The aim is to find out if text-editing is also a measure of schematic knowledge for solving paper and pencil physics problems. Traditionally, physics teaching has put much emphasis on solving convergent problems that contain necessary and sufficient information for their solution. A secondary aim of the study is to find out how well students can cope with problems that contain missing or irrelevant information.

There are differences between this study and Low and Over's in the design of the tests and the analysis of the results and these are described in the relevant sections below. This paper reports the quantitative part of the study; the qualitative part, which involves conducting interviews with students and which was not part of Low and Over's study, is to be carried out in the second phase of the study.

METHOD

Sample and testing.

Tests were administered to 130 Secondary 5 students (average age 16) from four schools about one to two months before the students took the Hong Kong Certificate of Education Examination. The students were therefore generally well prepared. Three tests were developed and administered.

Test A: Text editing This test consisted of 18 physics problems, 6 of which contain necessary and sufficient information for solution, 6 lack a component of information essential for solution, and 6 provide irrelevant information in addition to necessary information. The problems were of the usual type that appeared in physics textbooks and examinations. Students were asked to classify each problem by type (sufficient, missing, irrelevant) and, where appropriate, to identify the missing and irrelevant information. An example of each type is shown in Figure 1.

Low and Over used a cued format in the text-editing test and students were told that the problems in the test contained missing or irrelevant information which they had to identify. In the present study the three types of problems were randomized within the test and students had to classify them by type. It is thought that such a test format better tests students' knowledge of the problem structure.

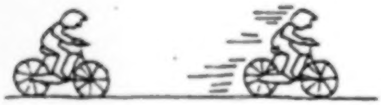
Test B: Problem solution This test consisted of the 6 problems in Test A which contain necessary and sufficient information for solution. Students were asked to solve these problems giving both their workings and answers.

Problem with Necessary & Sufficient Information:

1. In an emergency, a car travelling at 90 kmh^{-1} (25 ms^{-1}) is braked to a stop. If the car comes to a stop in 10 s, calculate the braking distance.

Problem with Missing Information:

6. A bicycle accelerates uniformly from 18 kmh^{-1} (5 ms^{-1}) to 72 kmh^{-1} (20 ms^{-1}). Calculate the bicycle's acceleration.



Problem with Irrelevant Information:

7. A ball of mass 0.4 kg falls from a height of 5 m above the ground. Find the ball's velocity on hitting the ground. Take $g = 10\ N\ kg^{-1}$ or $10\ ms^{-2}$.

Fig. 1. Examples of Physics Problems in the text-editing test.

Test C: Problem similarity This test consisted of six pairs of problems. In four pairs, the problems were similar in 'deep' structure (i.e. they required the same physics principle for solution) but were different in 'surface' structure or features. In the other two pairs, the problems were similar in their 'surface' structure or features (e.g. both were about the braking of car) but different in their 'deep' structure (i.e. they required different physics principles for solution). Students were asked to classify, supported with brief explanation, whether the problems in each pair were different or similar using their own criteria. An example of each type of problem pairs are given in Figure 2.

Problems similar in surface structure but different in deep structure:

1A In an emergency, a car travelling at $90kmh^{-1}$ ($25ms^{-1}$) is braked to a stop. If the car comes to a stop in 10 s, calculate the braking distance.

1B A car of mass 1000 kg is travelling at $90kmh^{-1}$ ($25ms^{-1}$). It is then braked to an emergency stop. If the average frictional force acting on the car is 2500 N, calculate the braking distance.

Problems different in surface structure but similar in deep structure:

6A A crane is used to lift a load of weight 5000N through a vertical distance. If the power output of the motor driving the crane is 1000W, find how long it takes to lift the load through 10 m.

6B A car travels on a level road at a constant speed. The power of the car at this speed is 40000 W. The air resistance and friction acting on the car is 2000 N. Find how long the car takes to travel 1000 m.

Fig. 2. Examples of Physics problems in the problem similarity test

Problems in all three tests were submitted to a panel of experienced physics teachers for scrutiny of their validity. All three tests were given in bilingual format (English/Chinese) to minimize any language difficulty that students may encounter. Tests A and B were administered one after the other in a double-period session (70 minutes) and Test C in a single-period session (35 minutes) several days later.

RESULTS

Table 1 gives the mean success rates of the different tests. Students were quite successful in detecting necessary and sufficient information (mean success rate 71%) and missing information (68%) within the problems, but many had difficulty in identifying irrelevant information (36%). The mean solution rate was high (84%) but there was a wide spread of scores (standard deviation 23%). Students' scores in problem similarity was low (mean 39%) showing that most students used a surface structure, rather than a deep structure, to determine whether problems are similar to or different from each other.

TABLE 1
MEAN SUCCESS RATE OF THE TESTS (N = 130)

	Mean success rate	Standard deviation
Sufficient (AS)	71%	22%
Missing (AM)	68%	21%
Irrelevant (AI)	36%	28%
Test A total score (A)	58%	15%
Problem solution (B)	84%	23%
Problem similarity (C)	39%	31%

Table 2 gives the correlations between the different tests. The solution rates correlated rather highly with the 'missing information' scores (0.53) but lowly with the 'irrelevant information' scores (0.25). In contrast, Low and Over reported very high corresponding correlations of 0.91 and 0.94 respectively. The problem similarity scores correlated moderately with the 'missing information' scores (0.45) and lowly with 'irrelevant information' scores (0.25) but were totally uncorrelated to the 'sufficient information' scores (-0.03).

TABLE 2
CORRELATIONS BETWEEN THE TESTS

	AS	AM	AI	A	B	C
Sufficient (AS)	-	0.24*	-0.01	0.57**	0.24*	-0.03
Missing (AM)		-	0.19	0.69**	0.53**	0.45**
Irrelevant (AI)			-	0.69**	0.25*	0.25*
Test A total score (A)				-	0.50**	0.34**
Problem solution (B)					-	0.39**
Problem similarity (C)						-

*$p < 0.01$ **$p < 0.001$

Comparison was made between students who used an entirely surface structure for classifying problems (i.e. scored 0 in the problem similarity test) and those who mostly used deep structure (i.e. score 50% or above). Out of 130 students, there were 28 in the 'surface structure' group and 40 in the 'deep structure' group. Table 3 gives the t-tests between the two groups on their mean scores in the different tests. It was found that the 'deep structure group' scored significantly higher than the 'surface structure' group ($p < 0.001$) in all except the 'sufficient information' exercise.

TABLE 3
t-TEST BETWEEN MEAN SCORES OF 'SURFACE STRUCTURE' AND 'DEEP STRUCTURE' GROUPS

	Surface structure group (N = 28) Mean	Deep structure group (N = 40) Mean	t
Sufficient (AS)	68%	69%	0.15
Missing (AM)	57%	79%	5.40**
Irrelevant (AI)	23%	44%	3.38**
Test A total score (A)	49%	64%	4.46**
Problem solution (B)	76%	97%	4.60**

*$p < 0.01$ **$p < 0.001$

DISCUSSION

On the whole, students' ability to identify problems that contained necessary and sufficient information for solution and missing information were much higher than their ability to detect irrelevant information within problems. This may be attributable to the way physics is taught in schools, that students are only drilled to solve convergent problems that contain necessary and sufficient information for solution. Problems that contain missing or irrelevant information are more taxing to students. They require students to be able to look for relevant information and to distinguish between useful and irrelevant information and have a good understanding of the relationship between the various physical quantities in the problem. They are a better test of students' knowledge of the problem structure. Physics teaching has long ignored such type of exercises and some remedy may be needed.

A direct comparison between the present study and Low and Over's is not possible since it was difficult or impossible to set physics problems that are exactly parallel to the algebraic problems. It would seem that the present study produced somewhat less 'convincing' results than Low and Over's in that the correlations between problem solution rate and text-editing scores were lower. However, it may still be argued that text-editing of physics problems, in particular the ability to detect missing information, is still, to some extent, a good measure of schematic knowledge.

Novices and experts have been shown to differ in their understanding and representation of physics problems (Larkin, McDermott, Simon & Simon, 1980; Chi, Feltovich & Glaser, 1981). While experts use a deep structure (i.e. use underlying physics principles) to determine whether problems are similar to or different from each other, novices rely on surface structures or features to categorize problems. The present study shows that students who used a 'deep' structure performed significantly better than students who used a 'surface' structure in detecting missing and irrelevant information within problems and in solving problems ($p < 0.001$). This result corroborates with the findings of the expert-novice research paradigm and lends some support to the claim that text-editing is a measure of schematic knowledge.

This paper reports the quantitative part of the study. The next phase will involve conducting interviews with students to explore their schematic knowledge of physics problems. It is hoped that the qualitative study will supplement and compliment the first phase of study and provide useful information on students' understanding of problems.

REFERENCES

Chi, M.T., Feltovich, P.J.H., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. Cognitive Science, 5. 121-152.

Larkin, J., McDermott, J., Simon, D.P., & Simon, H.A. (1980). Expert and novice performance in solving physics problems. Science, 208, 1335-1342.

Low, R. & Over, R. (1989). Detection of missing and irrelevant information within algebraic story problems. British Journal of Educational Psychology, 59, 296-305.

Mayer, R.E. (1983). Thinking, problem solving and cognition. San Francisco: Freeman.

Mayer, R.E. (1985). Mathematical ability. In R.J. Sternberg (ed.), Human abilities: an information processing approach. New York: Freeman.

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CHILDREN'S EXPLANATIONS OF AIR PRESSURE GENERATED BY SMALL GROUP ACTIVITIES

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ABSTRACT

Small groups of 7-8 year-old children undertook activities designed to challenge their ideas about air. The dominant impression from transcripts of their conversations and constructed explanations is one of the fluidity and context-dependence of children's ideas, rather than the existence of coherent and stable 'alternative frameworks' dealing with air pressure. Limitations of the generated explanations can be traced to localisation of focus in looking for causative effects, and premature closure. The transcripts show that interaction within groups was characterized by exchanges at significant cognitive levels.

INTRODUCTION

Much work has been done in recent years on the description and theoretical consideration of the many 'alternative conceptions' that children hold in relation to natural phenomena. Conceptions that children bring to the classroom are found to be not only rich and varied, but are surprisingly resistant to change through instruction (e.g. Champagne, Gunstone & Klopfer, 1982). This stability contrasts with findings that children can adopt a range of often contradictory conceptions to explain different phenomena (Biddulph, 1983). Other studies (Engel Clough, Driver & Wood-Robinson, 1987; Gauld, 1986) have demonstrated the stability of conceptions over time. Engel Clough and Driver (1986), in a study of the stability of alternative conceptions across contexts, found the evidence equivocal. Their results are consistent with earlier studies (e.g. Donaldson, 1978) that emphasize the context-dependence of children's responses to phenomena. In a more recent study Bloom (1990, 1992) has shown children's thinking to be extremely fluid, progressing via a rich selection of episodic knowledge, metaphors, interpretive frameworks and emotions/values/aesthetics. The extent to which children hold and use consistent 'alternative conceptions' over a range of contexts has implications for the extent to which we view conceptual change as 'radical restructuring' (Vosniadou & Brewer, 1987; Carey, 1985; West & Pines, 1984), and how we conceptualize the conditions that will favour such conceptual change (Posner, Strike, Hewson & Gertzog, 1982; Mitchell & Baird, 1986)

White (1987) argues the need for a 'theory of content' that would differentiate between different science topics and ideas in the way conceptual change occurs. He calls for more research on the formation and change of young children's conceptions, and for the development of a representation of cognitive structure that captures its fluidity. Most of the alternative conceptions research has sought to probe children's conceptions at fixed points in time. There is a need for a greater focus on the dynamics of children's ideas; the explanatory strategies they use, and the genesis of these strategies in the early school years. There is also a need to refocus attention on small group discussion as a strategy for encouraging conceptual change, rather than viewing the process as a private affair between teacher and individual student (see, for example, Borghi, De Ambrosis, Grossi & Zoppi, 1988). This paper describes an attempt to chart the dynamics of young children's construction of explanations of phenomena involving air pressure, as they work in small groups under the guidance of the researcher and classroom teacher.

The research was undertaken with the following questions in mind :

- What strategies do children use in constructing explanations of natural phenomena ?
- How stable are children's ideas when they engage in group based discourse about phenomena encountered in a classroom setting?
- Do children use explanatory conceptions in a consistent way, across contexts that scientists recognize as illustrating the same principles ?

METHOD

These transcripts arise from a sequence of two two-hour sessions with grade 2/3 children (aged 7 & 8) in a UK school. The sessions were taken by the researcher (RT), but the classroom teacher and aide both helped in organizational matters and in small group discussion at different points. The sequence of events in the sessions was as follows :

Session 1

After an introductory discussion to focus attention on the topic of 'Air', the class was organized into groups of three or four children. Each group was given a tape recorder and instructed in its use. The activities included :

- A plastic bag is put over a jar and the connection sealed. Children attempt to push the bag into the jar.
- Children insert a tissue into a glass and plunge it, upside down, into a bucket of water, observing whether the tissue became wet.
- Children float a small wooden boat in a bucket, and plunge the upturned glass over it to see if it would sink or float.

Each activity was intended to reinforce the idea that air has a tangible presence, and exerts a pressure on external objects in order to maintain its volume. Groups were asked to work towards an explanation of each activity that they all agreed on. Their group conversations were captured on tape. While the transcripts from Session 1 will not be discussed in detail here, they showed the children to be quite capable of maintaining a consistent focus in their conversations, recasting and refining their explanations as they reported to the tape or to an adult.

In the class reporting session, it seemed that the groups in general had come to an understanding of the idea of conservation of amount and volume of air. There were a number of references to the idea of the air moving aside or bursting the bag because 'when we pushed it in, the air had nowhere to go'. The explanations for the 'dry tissue' and 'sinking boat' activities were relatively consistent across groups, except that, in the case of the tissue, attention seemed to focus on ideas like 'water will not mix with the air', or 'the air is trapped', whereas in the case of the boat, ideas like 'the air is strong and pushed the surface of the water down' predominated. In order for an explanation to provide satisfaction, it is framed in such a way as to focus attention on the critical elements perceived in the situation; in the case of the tissue, the non-invasion of the water into the glass, and in the case of the boat, its depression by the air.

There were some instances of children, in reporting to the whole class, tending to focus on personal insights and experiments they had contributed to group understandings, rather than reporting on generalized understandings the transcripts showed they had achieved.

Session 2

After an introduction reminding the class of ideas generated in the previous lesson, the children were given a written exercise that probed their views on how we are able to suck liquid through a straw. A demonstration of air causing an evacuated can to collapse led to discussion of the idea that air presses on us with great force, an idea intended to focus the children's attention in the activities, which all relate to the scientific idea of differential air pressure acting on the surface of water.

The children were broken up into groups, each group performing a different pair of the following activities :

Fountain	A straw is attached through the lid of a sealed jar which contains water to above the level of the straw. When air is blown through the straw, water spurts up in a fountain-like effect once the mouth is removed.
Blocked funnel	Water is poured into a funnel tightly sealed into a jar. It does not pour through because of the pressure of air trapped inside.
Bird feeder	A full beaker of water with a saucer on the top is turned upside down. The water does not come out, unless the water round the bottom of the saucer is sucked with a straw.
Tricky straw	A straw is pricked in a number of places with a pin, so that it cannot be successfully used to drink through.
Magic finger	A can full of water has three holes punched in the bottom and one in the top. Flow of water through the bottom holes is controlled by closing and opening the top hole with a finger.
Upturned glass	A glass full of water with a piece of paper across the rim is upturned. The water does not spill out.

The groups performed the activities and discussed the questions associated with them, then reported their findings to the tape recorder. The children then went back to their original groups to demonstrate and report on their activities. These discussions were also taped.

The role of the researcher and teachers in each of these sessions was to circulate amongst the groups, clarifying tasks, encouraging discussion and focussing the children's attention on the questions. The session ended with a general discussion focussing on a few of the activities. Sections from each tape were transcribed; episodes comprising unfocussed talk, procedural conversations or unclear or disjointed talk were omitted.

The tape transcripts

The notion of differential pressure was quite difficult for these children, and their response to the activities tended to focus on other interpretations. Often they were content with simply describing the sequence of events. Even with further encouragement from teachers to explain, the explanations were sometimes very cursory, dealing with a descriptions of the apparatus and method, and elements of the result that were not at all central. Many children seemed preoccupied with the 'trick' aspects of the activities and the explication of the trick in many cases was viewed as sufficient explanation. There were, however, many examples of groups focussing usefully on generating explanations of these 'discrepant events', and it was possible with these groups to chart the development of ideas within the group, and across groups in the explication of ideas thus generated.

Explanation of events in terms of human action was not uncommon. The 'fountain' was explained as water being 'blown out', as was the 'bird feeder' when a straw was used to blow air under the rim. Quite often the construction of explanations based on causal sequences, instead of superficial observations based on human action, or simple descriptions of how to make the event 'work', required close involvement of adults. This had not been true of the activities in the first session, where the explanatory concepts were much simpler.

These can also be viewed as examples of 'premature closure' (Baird & White, 1982), in that the details of the interaction between the air and water were ignored, particularly the time lag between blowing and the spurt of water in the case of the fountain. One group explained the 'blocked funnel' in terms of the squeezing of the stopper by the flask rim, physically closing off the funnel. The explanation is consistent, but implausible if the properties of plastic (its rigidity) are considered. The question arises as to whether this inferior strategy is due to a lack of wider domain knowledge, or to an unwillingness to put inferences to a wider set of tests.

In more successful attempts at an explanation, the idea of the water being 'trapped' was used, just as the idea of air being 'trapped' appeared quite often. In the following exchange, Dean shifts his focus substantially, with no apparent antecedents to his idea of the outside air exerting a force at the bottom.

D The water didn't come out because... the top of the beaker there was air, and the bottom there was a plate.. and the water was trapped. [Later]...I think... I think water is trapped. 'Cos the air was at the top there, it was forcing it.
RT What was forcing what ?
D The air was forcing the water not to come out.

(Presumably the water was squeezed between the air and the plate... a superficial analogy based perhaps on the previous exercise where air is trapped in an upturned glass.)

Ten minutes later, RT returns and asks, 'Why didn't the water come out?'

C Because the air was all in it, 'cos we didn't take the plate off.

RT Right... so what difference does that make ? .... Dean, what do you think ?

D I think because the air was forcing it back in and the air was forcing it out and the plate was full of water.

RT So when you say the air was forcing it back in... which air do you mean ?

D Air all outside.

(Clara considers the existence of the plate sufficient to explain why the water doesn't come out. Dean, however, has been widening his perspective in the meantime to include the air outside.)

It proved very difficult for children to widen their perspectives on possible causative agents, beyond the immediately obvious elements of a situation. The outside air was rarely mentioned as a factor. Sucking was commonly held to explain why the card does not fall off the upturned glass, and this tends to be associated with the air trapped in the glass. One group held this view, but in order to test their hypothesis tried to run the trick through with no air by putting the card on under water. They still found a bubble, and took this as confirmation of their hypothesis, associating the upward motion of the bubble with an upward suction force on the card.

K ... the air was at the bottom and when you tipped it upside down the air sucked up the card. It was like a magnet to it... (The magnet analogy was a persistent feature of Karen's explanation.)

N ... the air goes the air bubble goes up to the top and we tried with one... we put the glass under water so we put the green plastic card on ... (? .. and it worked) ... we tried it full up to the top...

J ... the air always goes up, so when it's upside-down it sucks it up. (Both of these students associate the upward motion of the bubble with an upward force on the card.)

Children were quite capable of accommodating parallel views of events. In one of few explanations of the card trick in which the outside air was mentioned as a factor, some clinging to the 'sucking' theory is still evident.

E We think it's because the air is pushing up and keeping the card on and also the water is sort of sucking it.

The 'tricky straw' activity gave rise to an interesting phenomenon. A few groups, observing spray coming from the holes in the straw, embellished this and incorporated it into their suction theory of drinking. Lindy explains the effect:

L The liquid kept on falling out the hole and .. um.. so she couldn't drink it very well. That's what I think.

Some time later, she is asked why the holes in the straw make a difference.

L Is it when you suck in, all the air's going out.... When you can suck up all the air goes outside so the the air can't ... can't catch hold of the drink...(She confuses the direction of air in relation to the holes.) ...when we try and suck up all the air goes out the holes.... I think ....

This confusion about direction of air, evident above, is also a feature in explanations of the 'magic finger' activity. Dean, in referring to a demonstration of this 'trick', attributes the flow of water to the action of the finger, pushing air into the can, and in group discussion actively insists on this interpretation. RT then arrives and asks for the group view.

RT What about the can ? Why is it that when you put your finger on the top it stops the water coming out.. John?

J Because it's stopping the air from coming out the top.

C Well when you put your finger on it and um.. the water doesn't go out... um... all the air is pushed in so the water can't go out... um.. and when you lift the finger off ... um the water can get out.

RT Why does lifting your finger up allow the water to get out ? ... Dean do you know ?

D Yeah. 'cos its a bit like Clara's but Clara just got a bit mixed up. When you put your finger down.... it forces the air down.... to the water so the water comes out of the hole. When you let it out air just comes out that hole out the top and the water stays in 'cos the holes are not big enough for it to just go straight through.

Dean's is quite a good account, based on the idea of squeezing, together with a subsidiary explanation of why the water doesn't come out without being forced. He misrepresents his observation of when the water comes out, in order to hold to this theory. There is in fact some small amount of leakage of water if the finger is pressed hard, due to flexibility of the can.

There were a few instances of ideas developed in one group carrying across to related activities. Clara, for instance, had acquiesced in Dean's account of the 'magic finger', above, but in running through an explanation for her home group reverts to her original sequence of events, and adds an insight that didn't appear in the previous group; that of air at the bottom stopping the water coming through the holes. We can, perhaps, trace this back to Dean's explanation of the bird feeder, to which she was a party.

N What I think happens is that when you hold the top no water comes down because the air is trapped..Because of the water by that. But when you take your finger off there's air coming out so that's why the water falls through. Is that right Clara ? (Narelle associates the escape of air from the top hole with the idea of the water being trapped.)

C I'm going to say. In the top there's a hole. In the water there's three holes.. and ... the air is at the bottom stopping it ... the water.. when .. you put your finger on it.... like that. And when you take it off..... um... it allows the water to go through. (Clara does not take up Dean's explanation, although she appeared to agree with it at the time.)

In this sequence Clara and Narelle give differing, if not contradictory views, yet do not acknowledge the difference and do not attempt a reconciliation.

Not only were inconsistencies between different children's explanations often ignored, but children applied their insights inconsistently across contexts. When Narelle demonstrates the 'fountain' and asks if anyone knows what is happening, Clara offers a very coherent explanation that nevertheless ignores her insight into the pressure of outside air :

C I do... I do....When you blow air into the .... water there's lots of bubbles and when you get .... and the air in the water.....(interruption on another point, but Clara persists) ... when you blow air into it the air's trapped inside... and when it .... because your mouth sits there ... and when your mouth lets go it forces its way up....that's what I think and I'm brilliant. (Clara clearly acknowledges the idea of air trapped under pressure and released when the mouth is removed.)

On the other hand, she is very quick to say 'The air's sucking it on', as the explanation for the upturned glass and card trick. Children seemed to craft their explanations according to their mental images of the salient features of the phenomena, and insights gained in one context were readily abandoned in another.

DISCUSSION

Children's explanatory strategies

In these transcripts a dominant impression is one of the fluidity of children's ideas. They were quite capable of adjusting their thinking to accommodate other children's statements, of holding their peace yet choosing to agree or not with the group view, and of adjusting their viewpoint to accommodate different contexts. They were capable of consistent and plausible reasoning, and of designing and carrying out subsidiary experiments to check inferences. Observation was used to support or reject hypotheses. In this respect, subsidiary observations were sometimes leapt upon to support hypotheses that were essentially incorrect.

Many children, while explaining the same phenomenon on different occasions, developed successive embellishments, some of which showed the ability to generalize the ideas very quickly to incorporate either a wider set of ideas, or a more complete explanatory sequence; 'filling in the gaps', as it were. These children seemed to be, over a short period of time, moving up the SOLO taxonomy scale (Biggs & Collis, 1982), bringing more careful thought to bear with each telling.

Children displayed a consistency in explanation from group to group. They tended to stick to an explanation, particularly if they had arrived at it and argued for it. If it was contradicted later, they tended to subtly accommodate new ideas rather than switch over immediately.

Parallel explanations were sometimes resorted to, as in describing the water in the 'magic finger' being kept up by both the air outside and the air inside.

When explaining phenomena to the whole class, children tended to focus on insights they had generated themselves, or additional experiments they themselves had performed.

There were many cases of flashes of insight that had no obvious antecedents; they did not seem to come from anywhere in particular. At times, insights shown in one situation were not matched by comparable insights by the same child in related situations.

In situations that were somewhat different, children sometimes carried across a 'mental model', such as water or air being 'trapped'. The idea of air taking up space and the necessity for air and water to compete for space seemed to carry across the various activities. They did not achieve a generalized theory of air pressure, because they seemed incapable of switching their attention from the site of immediate action to the interplay of pressures outside and inside containers.

Where there were explanations that were confused or missed the point, the main problem was they they did not adopt a rigorous enough strategy of cross-checking their assertions against observations or particularly against other knowledge. We could perhaps view this as a lack of knowledge relevant to the domain, or as an inferior cognitive strategy (not continually cross-checking with other knowledge), or as a combination of these.

Children's 'interpretive frameworks' of air pressure

A number of explanatory ideas appeared in more than one group, across more than one context :

- The idea of water or air being 'trapped' (Magic finger, Bird feeder).
- The idea of air replacing water to allow it to escape, or competing with water for space. (Magic finger, Blocked funnel, Fountain)
- The focus on enclosed air as a causative agent, which could either push (Fountain, Blocked Funnel) or 'suck' (Upturned glass, Tricky straw) water to keep it up or pull it up. The direction of force was often ill-defined. The movement of air in and out of tubes and holes was often ill-defined, or incorrect.
- Identifying a human causative agent as the mode of explanation was common. (e.g. the press of a finger, the sucking action of the mouth, blowing water out of the 'fountain' or the bird feeder)
- Push from the outside air. (Upturned glass) In rare cases only was the notion of differential pressure resorted to.

This is a richer set of frameworks than those discussed by Sere (1982), who found that 11-13 year-old children focus their explanations on movement of air and force, and find it difficult to associate effects with immobile air.

Engel Clough and Driver (1986) define an 'alternative framework' as a category of response that is used for more than one phenomenon. If we adjust the terminology to include ideas that have some scientific validity, on that basis one should classify all but the last idea in the above list as 'interpretive frameworks' (Bloom, 1992), representing useful and persistent ideas. These children seem to be operating with a 'cluster' of interpretive frameworks that represent multiple, sometimes contradictory perspectives on the interaction of air with water. The existence of a coherent 'alternative framework' that is applied consistently across a range of phenomena is not born out by these transcripts. The idea of 'sucking', for instance, is persistent in the case of the upturned glass and the straws, but is not used in the magic finger, where different images prove effective. Children cast around for explanatory notions to suit specific situations, and even in the seemingly identical events of the tissue remaining dry, and the boat being 'sunk' under an upturned glass, their understandings are expressed differently to suit the different focus of their attention in each case. This view accords with Driver's (1992) description of 'common sense' science as being utilitarian and adaptive to circumstances.

Many of these children are quite capable of applying rules of logic and rules relating to the need for hypotheses to match observations, but in the absence of a generalizing principle they are forced to do so in a sporadic way, using analogy, mental images and comparisons that are often superficial, because each case is somewhat different and needs a slightly different focus. They do not have access to the wider vocabulary, experiences and ideas that would allow them (or predispose them) to develop an interpretive framework that could be applied across all these phenomena, and which would therefore accord with the 'principle of parsimony' (Driver, 1992) of scientists' science.

It seems useful, therefore, to characterize these transcripts in terms of a set of explanatory strategies that allow the generation and application of a range of conceptions, but which are limited in their generalizability because of the limited domain knowledge of the children. In addition, and perhaps related to this, they seem inexperienced in the application of a wider set of criteria and group procedures by which they might judge their explanations more critically. The proper role of the teacher, in this event, would be to act as critical friend, pointing out relevant features of events they seem predisposed to ignore, drawing attention to inconsistencies in their explanations (either within, or between children), and suggesting further observations or experiments that might clarify their thoughts. This, in fact, tended to be the way the participating adults acted in these sessions.

REFERENCES

Baird, J.R. & White, R.T.(1982). Improving self-control of learning. Instructional Science, 11, 227-247.

Biddulph, F. (1983). Students' views on floating and sinking. Working paper No. 116 of the Learning in Science Project (Primary), University of Waikato: Centre for Research in Science Education.

Biggs, J. & Collis, K. (1982) Evaluating the quality of learning: The SOLO taxonomy. New York: Academic Press.

Bloom, J. (1990). Contexts of meaning: young children's understanding of biological phenomena, International Journal of Science Education, 12 (5), 549-561.

Bloom, J. (1992). The development of scientific knowledge in elementary school children: A context of meaning perspective, Science Education, 76 (4), 399-413.

Borghi, A., De Ambrosis, C., Grossi, M. & Zoppi, D. (1988). Knowledge of air: A study of children aged between 6 and 8 years. International Journal of Science Education, 10 (2), 179-188.

Carey, S. (1985). Are children fundamentally different kinds of thinkers and learners than adults? In S. Chipman, J. Segal & R. Glaser (eds.) Thinking and learning skills Vol. 2, pp 485-514, New Jersey: Lawrence Erlbaum.

Champagne, A., Klopfer, L. & Gunstone, R. (1982). Cognitive research and the design of science instruction. Educational Psychologist, 17, 31-53.

Donaldson, M. (1978). Children's minds. New York: Fontana/Collins.

Driver, R. (1992). Progression in students' science conceptions: Research findings and their implications for curriculum planning. Paper presented at the conference of the Australasian Science Education Research Association, Hamilton, New Zealand.

Engel Clough, E. & Driver, R. (1986). A study of consistency i n the use of students' conceptual frameworks across different task contexts. Science Education, 70 (4), 473-496.

Engel Clough, E., Driver, R. & Wood-Robinson, C. (1987). How do children's scientific ideas change over time? School Science Review, 69, 255-267.

Gauld, C. (1986). Models, meters and memory. Research in Science Education, 16, 49-54.

Mitchell, I. & Baird, J. (1986). Teaching, learning and the curriculum-1: The influence of content of science. Research in Science Education, 16, 141-149.

Posner, G., Strike, K., Hewson, P. & Gertzog, W. (1982) Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66 (2), 211-227.

Sere, M. (1982). A study of some frameworks used by pupils aged 11-13 years in the interpretation of air pressure. European Journal of Science Education, 4 (3), 299-309.

Vosniadou, S. & Brewer, W.F. (1987) Theories of knowledge restructuring in development. Review of Educational Research, 57 (1), 51-67.

West, L. & Pines, L. (1984). An interpretation of research in conceptual understanding within sources-of-knowledge frameworks, Research in Science Education, 14, 47-56.

White, R.T. (1987). The future of research on cognitive structure and conceptual change. Paper given at a meeting of the AERA, Washington D.C.

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ABSTRACTS AND RESEARCH NOTES

VCE CHEMISTRY AS A CURRICULUM INNOVATION

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RESEARCH NOTE

The Victorian Certificate of Education (VCE) Chemistry course was introduced in 1990. It was part of a complete restructure of the post-compulsory years of secondary schooling in Victoria and was intended to cater for a much wider spectrum of the 17+ age cohort than the previous chemistry course.

In this study, we wished to focus on the dissemination process of introducing VCE Chemistry and how the meaning of its message about curricular changes was shared. We set out to design a study that would answer the following questions:

- What meanings did teachers attach to major changes in the VCE curriculum?
- How do meanings change?
- Which meanings became shared through dissemination alone and which seemed to need other experiences?

We were aware that to have any hope of getting at the meaning others attach to words and messages it is necessary to listen not simply to answers to questions but also to explanations of these answers. This meant clinical questioning or open-ended interviews with deliberate probing as the means of data collection.

We were more interested in the sorts of meanings that might exist and their changes than we were in how many teachers had which meaning. Quota sampling within our resources rather than representative sampling was thus the way we identified teachers to interview.

METHOD

There were three distinct phases to this project. Phase 1 involved interviewing the course study writers in 1989 to gain an appreciation of the meaning they attached to eight aspects of the curriculum change that were either novel or much changed in the intentions of the writers. These were: content; contexts and focal questions; work requirements; practical work; assessment; changes in teaching; science, technology and society approach and student learning.

The second phase involved interviewing 32 teachers from both country and metropolitan Victoria. This phase was undertaken in late 1989, fifteen months before teachers were to teach this course. Several workshops and seminars to communicate the nature of the new course had been held that year.

The third phase involved interviewing 30 teachers who had now taught at least one year of VCE Chemistry. This phase was undertaken in late 1991 and early 1992. Some were from phase 2; others were first-year and experienced teachers who had not been a part of the earlier phases of the project.

FINDINGS

Three new aspects of VCE Chemistry, namely contexts, focal questions and work requirements, are used to illustrate what was achieved in this research.

Contexts

Chemistry courses throughout the world differed little in the actual content that was taught. The major change was a contextual approach: the way things were taught in the classroom. This change seemed to be quite well recognized by teachers as early as 1989, fifteen months before they were to teach this course.

Phase 3 teachers' responses to contexts varied. The use of the term "context" differed, and this may be in part due to its obvious absence from the Chemistry Study Design document.

Focal Questions

The intentions of the study design with respect to the use of focal questions are to define the area of study in terms of the context of chemistry, technology and society. The intentions are not to define the chemical phenomena, knowledge, concepts or activities. These aspects do need to be considered, however, in order to resolve the focal questions.

The term "focal questions" was not identified by any of the study writers. The study writers constantly refer to the idea of "contexts" and yet this term is a notable exclusion from the formal study design document. The formal document formulated by the Field of Study Committee (FOSC) refers only to "focal questions". These are not synonymous terms and this highlights the difficulty that exists when trying to share meaning between many different groups.

When asked what they thought focal questions were, teachers in 1989 offered a wide range of responses. At this stage, it appeared to the researchers that some teachers read and listen to VCE information quite differently from others. Some had a teacher-centred approach to this new course. These were the ones who had difficulty in seeing the purpose of focal questions.

Alternately there were teachers who saw the VCE, the sequence of things, the focal questions and so on as being for the students. They had the idea that these features would make learning different, better or easier.

Teachers in the third phase still held diverse views about focal questions. The purpose of the focal questions had become much clearer with experience, but the use of them in terms of what was happening in the classroom varied significantly.

Work Requirements

The study writers took the prescriptive element of work requirements being common to all VCE subjects as an opportunity to force teachers to focus on how they and their students learn. The work requirements imposed on teachers the methodology they were to adopt. The teachers would find it very difficult to reorganize their old HSC course to fit the new structure.

Many phase 2 teachers were resentful of this study design because they believed it was imposing on teachers the way they should teach. Once again the polarization between teachers who see themselves as teachers and those who see themselves as facilitating learning was highlighted.

Phase 3 teachers' experience of work requirements meant that generally there had been acceptance of the new strategies incorporated in work requirements as useful mechanisms for teaching in some cases and learning in others. There was still a sense of outrage that professional teachers were being told "how to teach".

CONCLUSION

The difficulty of sharing meaning of curriculum intentions between different groups is highlighted in this study. The acceptance of the novel features of the Chemistry Study Design is mixed. The longitudinal nature of the study helped to identify the difficulty teachers had in understanding the meaning of these novel features although the experiences of teaching units in the VCE chemistry course have enabled some teachers to shift in their construction of the meaning of the words and messages around them.

REFERENCES

Victorian Curriculum and Assessment Board (1991). VCE Chemistry Study Design. Melbourne: VCAB.

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THE EFFECT OF QUESTION FORMAT IN REVEALING THE QUALITY OF STUDENT LEARNING OF SOME BIOLOGICAL CONCEPTS

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RESEARCH NOTE

The SOLO (Structure of the Observed Learning Outcome) taxonomy has been used to assess the quality of students' responses in various fields for both instructional and assessment purposes. It has also been proposed as a logical means of breaking down the general aims of science education into specific classroom aims and activities and for providing a reliable means of criterion based assessment (Collis & Biggs, 1989; Pallett & Rataj, 1992). This research note describes the results of the initial phase of a larger study of the use of the SOLO taxonomy to evaluate students' understandings of some concepts basic to the study of senior secondary biology.

Both open and closed (superitem) format questions have been used when investigating student understanding in a number of subject areas. The 'open' format questions encourage students to give their 'best' answer without describing the required structure. The 'closed' format questions are framed in such a way that students are at the least directed to structure their answers in a certain way, namely, conforming to the targeted SOLO level. The intention is to obtain the best answer a student is capable of giving and thereby approximate that student's level of understanding in that topic. Research in the use of superitems in mathematical problem solving (Wearne & Romberg, 1977) indicated that the superitem structure provided a more refined measure of students' abilities and yielded more information about these abilities than open-ended questions. If the students' best responses are required, which is the best format to use? This phase of the project was designed to compare the quality of response of students to the two question formats and answer two questions:

- Do open style questions yield responses which underestimate the true level of understanding of a student?
- Do closed style questions provide a prompting effect and thereby secure the student's best answer?

The subjects for this study were 14 Diploma of Education students in a senior secondary science methods unit. During the week following the administration of the test questions, students were interviewed to clarify their understanding of some of the questions and to examine their beliefs about the kind and amount of information required for satisfactory completion of each question. They were then asked to compare the open format questions with the last superitem question to find out if they perceived the questions to require answers of different quality.

Test Questions

Open format: These questions were presented in standard essay question format in which student were asked to supply as much information as possible. There were three questions, each centering on a different concept: natural selection, biogeochemical cycles and food webs/biomass pyramids.

Closed format: The closed items were designed according to the SOLO superitem format (Collis & Davey, 1986). Three superitems in biology were constructed based on a previous trial and covered the same concept areas as the open format questions.

After scoring the students' responses on the basis of correctness, answers to both superitem questions and open format questions were scored according to their structure: they were assigned to SOLO levels according to established criteria. Superitem response patterns were examined using Guttman Scaling. The results demonstrated that within the superitems there does seem to be prompting occurring. No responses were scored as extended abstract, however, so under the conditions of this study, the superitem structure does not seem to elicit students' best responses. This is most clearly seen when the structure of 'extended abstract' question of superitem is compared to that of the open question. Most responses to open questions were of a higher structural level than those responding to the superitem questions. The results of this study demonstrated that question format does appear to effect the SOLO level of response of this group of students. If the SOLO Taxonomy is to be used in the setting of specific teaching objectives and as a means of criterion based assessment such effects need to be considered.

REFERENCES

Collis, K.F. & Biggs, J. (1989). A school-based approach to setting and evaluating science curriculum objectives: SOLO and school science. The Australian Science Teachers Journal, 35 (4), 15-25.

Collis, K.F. & Davey, H.A. (1986). A technique for evaluating skills in high school science. Journal of Research in Science Teaching, 23 (7), 651-663.

Pallett, R. & Rataj, J. (1992). Criterion based assessment and school science. Part 2: Choosing areas of study. The Australian Science Teacher's Journal, 38 (1), 54-56.

Wearne, D.C. & Romberg, T.A. (1977). DMP accountability tests (working paper no. 217). Madison: Wisconsin Research and Development Center.

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IMAGES OF SCIENCE TEACHING: AN EXPLORATION OF THE BELIEFS OF PRESERVICE SECONDARY SCIENCE TEACHERS

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ABSTRACT

Science graduates who enrol in a preservice Graduate Diploma of Education bring with them many years of experience as learners of science. These will have enabled them to develop implicit theories about what a science teacher is and does. Such implicit theories almost certainly affect the process of becoming a teacher, and may prove persistent despite the input from University and school during the Dip. Ed. year and beyond. This paper presents the research method and results obtained from a group of graduates on entry to their Diploma course. Concept maps and Repertory Grid interviews were obtained from eleven graduates, with varying life experiences. The paper presents analyses of these and explores emerging themes.

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TEXTBOOK TREATMENTS AND STUDENTS' UNDERSTANDING OF ACCELERATION

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A single science textbook often provides the syllabus for courses at upper secondary and tertiary levels, and may be used as a principal source of information or explanation. The research reported in this paper challenges such practices. The ways in which the concept, acceleration, is treated in physics textbooks is compared with understandings of the concept demonstrated by final year secondary (year 12) and first year university students. Some students' understandings are shown to be incomplete in ways that parallel misleading or inaccurate textbook treatments of the concept.

In addition to misleading or inaccurate statements, the limitations of some textbook treatments of acceleration were found to include: lack of attempts to make explicit relationships with other concepts; failure to point out when it is appropriate to use particular definitions or that an alternative definition might be more appropriate in specific situations; inclusion of operational definitions without conceptual explanations; and a focus on quantitative treatments while overlooking the development of qualitative understanding. Two principal aspects that distinguished the ways in which the students understood acceleration were identified: the relation between acceleration and velocity; and the relation between acceleration and force(s). The results of the study have implications for teaching and, in particular, for the use of textbooks in teaching. These implications are discussed in the paper.

This paper has been accepted for publication in the Journal of Research in Science Teaching. Copies are available from Gloria Dall'Alba, ERADU, RMIT, GPO Box 2476V, Melbourne. Vic. 3001.

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WHERE ARE THE SCIENCE AND MATHS TEACHERS ?
A FIFTEEN YEAR FOLLOW-UP STUDY.

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RESEARCH NOTE

Purpose and Summary

Facing challenges to the efficacy of end-on teacher education has led me to ask serious questions about where the responsibilities of teacher educators to their students lie. Would graduate students' long term career interests and those of society at large be best served by a change in the locus of teacher training from universities to schools?

Information collected in questionnaire and interviews with students who had enrolled in mathematics and science at Melbourne University points to the limits of the "practical" argument that the professionalization of science teaching lies in substantially more school practice.

Method and Sample

A questionnaire was mailed to the 425 of 535 full-time Science/Maths Dip. Ed. graduates from the years 1976-90 for whom an address could be found. Of these, 268 (64%) were returned, and at least 50% of the graduates in each year group were in the sample. The gender balance in the sample was comparable with the original class lists; there was no reason to believe that the sample was unrepresentative. Telephone and site interviews were conducted with those who indicated interest.

Data

Information was collected about personal and family background, undergraduate studies, method affiliation, career choices and the value attributed to their education studies in their chosen work. Only some data about careers can be reported here.

Careers of Science and Mathematics Teachers

The average age of the group was 32 years (compared to the state average of about 45 years). The years covered by the survey were years of virtual full employment for science teachers. Twelve percent never taught, choosing an alternative career from the outset. The others have taught for an average of 5.7 years. In 1991, of the group that has taught, 46% had left full-time teaching. Table 1 shows the employment in 1990 for the 262 of the 268 who provided answers to this question.

Of all those teaching in 1991, 8% were employed in Catholic schools, 24% in independent schools, 19% in Victorian country state, 36% in north/west suburban and 14% in south/east suburban Melbourne state schools. From a peak of 77% of former students teaching secondary full-time in 1984 the figure has dropped to 42% in 1991. In 1984 63% of the whole sample were employed in state schools, but the figure fell steadily to 39% by 1991, reflecting more frequent departures from teaching. Amongst the alternative careers were: lecturing in the post-secondary education and training sector, in the health sector; sales representative, pharmacist, chiropractor, dentist, psychologist, rehabilitation counsellor, in finance, insurance and banking, in technical services and training; in computer systems; geologist, chemist, meteorologist, communication engineer, embryologist. Ninety percent of all respondents felt their occupation demanded skill in communication and personnel management and 74% felt it drew on their maths/science background.

TABLE 1
1990 EMPLOYMENT

Employment	n	(%)
Teaching fulltime	124	42
Teaching parttime	16	6
Home duties (full)	18	7
Research/study	13	5
TAFE/tertiary teaching	35	13
Private enterprise	30	12
Public service	21	8
Self employed	5	2

Factors Important in Career Choices

Excluding the 34 who wanted to be at home fulltime or parttime, 104 of the 228 employed have either never taught or have left teaching. For them the most important factors were "the opportunity for a more interesting career elsewhere" (73%) and "better pay elsewhere" (50%). The next most important factors were "difficulty in maintaining discipline in class" (32%) and the "low public esteem of teaching "(30%). Those teaching full-time in 1991 (n=124) mentioned a number of factors in their continuing commitment. "Response from students to my efforts", "an interest in school science/maths", "an interest in teaching as a profession", "an interest in adolescents", and "security of income" were regarded as important by more than 80% of this group. Amongst the factors rated as least important were, "response from the local community", "superannuation", "level of income" and "response from other teachers to my efforts". Asked about their future plans to teach the whole group (n=268) gave the responses shown in Table 2 to the questions, "Do you plan to be teaching next year, in 5 years time and in 10 years time?"

TABLE 2

FUTURE PLANS TO TEACH
(figures %)

	Yes	Undecided	No
Next year?	54	7	39
Five years time?	37	38	25
Ten years time?	24	52	24

Some were interested in returning to teaching and many more would be looking after children of their own in the next 10 years. Only 25% had completely abandoned teaching in the medium to long term. Evidence for a continuing vocational interest is provided by responses to a question about the level of satisfaction with their choice of career. The teachers as a group were slightly more satisfied than those employed elsewhere (Table 3).

TABLE 3

LEVEL OF CAREER SATISFACTION
(figures %)

		not at all/quite	somewhat	highly satisfied
Teaching Full Time	n = 124	12	52	36
Not Teaching	n = 100	23	46	31

In interviews many who had left teaching said they still found the idea of teaching appealing. They felt the Diploma of Education program most helped them by expanding their view of maths and science, increasing their understanding of public education issues and in new knowledge gained. In these there were no discernible differences between those currently teaching and in schools and those exployed elsewhere. Fewer than 20% wanted an entirely school-based Diploma of Eduction programme.

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TECHNOLOGY IN THE CURRICULUM: A VEHICLE FOR THE DEVELOPMENT OF CHILDREN'S UNDERSTANDING OF SCIENCE CONCEPTS THROUGH PROBLEM SOLVING.

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ABSTRACT

This research was carried out over a period of ten months with children in Grades 2 and 3 (aged 7 and 8) who were participating in a sequence of technology activities. Since the introduction into Victorian primary schools of The Technology Studies Framework P-10 (Crawford, 1988), more teachers are including technology studies in their classrooms and by so doing may assist children's understanding of science concepts. Children are being exposed to science phenomena related to the technology activities and Technology Studies may be a way of providing children with science experiences. 'Technology Studies' in this context refers to children carrying out practical problem solving tasks which can be completed without any particular scientific knowledge. Participation in the technology activities may encourage children to become actively involved, thereby facilitating an exploration of the related science concepts. The project identified the importance of challenge in relation to the children's involvement in the technology activities and the conference paper (available from the first author) discusses particular topics in terms of the balance between cognitive/metacognitive and affective influences (Baird et al., 1990)

REFERENCES

Baird, J. R., Fensham, P. J., Gunstone, R. F. & White, R. T. (1990). Teaching, learning, research, and change: common processes; common demands; common outcomes; common rewards. Paper presented at the annual conference of the Australian Teacher Education Association.

Crawford, J. (ed.) (1988). The Technology Studies Framework P-10, Curriculum Branch. Melbourne: Ministry of Education, Victoria.

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DISTURBING THE BOUNDARIES:
THE SCIENCE/LITERATURE MEMBRANE

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RESEARCH NOTE

Constructivist theories of learning have encouraged us to look for the connections learners make when information is received. In science education, we have naturally tended to concern ourselves with the connections between scientific concepts. Research is beginning to uncover the connections between incoming scientific information and non-scientific content of the mind. Concept maps have been valuable here, showing the kinds of connections that are made when such words as 'energy', 'force', and 'living' are explored.

From 1988 through the current year, the authors have organised a short story competition for science students in Australian secondary schools. Sponsored by the Royal Australian Chemical Institute as part of its National Chemistry Week activities, the competition is based around writing a fictional short story in which chemistry played a major role. As a result, there are now over 229 short stories to examine using content analysis techniques for the images of science and of scientists portrayed. This paper discussed some interesting revelations about the way scientists are imagined by students, and about the social world they inhabit. Attitudes, values and behaviours of (mostly) male scientists appeared consistently and clearly in student stories. These results were examined against a background of comparative research in the area of children's perceptions of science and scientists.

About one third of the stories showed two distinct and unintegrated styles. These were a literary fiction style, for example comic book, war, adventure, mythical morality adventure, romance and adolescent social realism. These literary styles were often alongside classroom or school science textbook styles.

An objective of the competition was to stimulate imaginative interest in science, and to provoke thought among students about the ways in which science was contiguous with real and imaginative experience. Certainly, the products of this short story competition have suggested that science stories provide rich possibilities for humanistic exploration. The competition revived ideas about the 'two cultures'; they seem clearly evident, and separate, in many of these stories. Both cultures, it seems, have much to gain if science teachers feel able to involve humanities teachers and secondary students in a joint writing enterprise. On the whole, stories from English classrooms are quite different to, and remote from stories from science classrooms. The two cultures are so distinct in many students' minds that ideas must be written in two separate styles, which cannot be reconciled even within the one story.

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COMMUNITY INVOLVEMENT IN RESEARCH AS A FORMAL AND INFORMAL MECHANISM FOR SCIENCE EDUCATION: PROJECT EGRET WATCH

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RESEARCH NOTE

Informal science learning has received increasing attention in recent years but few studies have been carried out into the process of learning outside of school or into the interactions of learners with other sources of information. Informal and formal science and environmental learning takes place through community involvement in ornithological research at the Wetlands Centre at Shortland in NSW Australia, a centre for environmental education, conservation, research and passive recreation in wetland settings situated at the edge of extensive swampland in the Hunter River estuary . The Centre has classroom, library, theatrette, display, office and cafeteria facilities.

A colony of egrets on the site and colonies at other NSW locations have been the focus of Project Egret Watch, a research study into the breeding biology, ecology and migration of the egrets, which has produced publications in the scientific literature on breeding biology, ecology, migration and field techniques. Adult and school-aged volunteers assist with wing-tagging of the birds at the breeding colonies and as field observers throughout Australia and New Zealand. Feedback to volunteers, the media and to visitors to the Centre provides a vehicle for both formal and informal science and environmental education. Participating schools have their own newsletter.

Evaluation of the success of Project Egret Watch as a vehicle for learning has been informal to date, based on observational, anecdotal and participant feedback. There is a need and significant potential for a range of science education research studies related to the Project Egret Watch, in the cognitive and affective domains as well as into sociological aspects. Questions such as what specific cognitive and affective learning outcomes result in the formal, non-formal and informal domains, who is reached by the informal mechanisms operating in relation to the project, such as the media and the outreach initiatives, and what are their characteristics, are all worthy of study. A program such as Project Egret Watch would need the development and application of new measures and multiple evaluation methods.

There has been little research into the outcomes of the work of field study centres of the Wetlands Centre type. Participants in Project Egret Watch are helping with real research and contributing to results which are published in the scientific literature. The feedback to participants is couched in lay terms and often features "human interest" aspects, but attempts are made to keep it scientifically accurate and incorporate aspects of methodology and conservation outcomes as part of the broader educational objectives. The outcomes are not really measurable in traditional science education research terms.

The Wetlands Centre currently does not have the resources to undertake such studies in its own right. It is, however, interested in providing universities with access to its programs and facilities in order that such research can be carried out. There is plenty of scope for small-scale course-related studies as well as minor theses and higher degree studies. The potential for obtaining funds by joint grant applications exists. There is scope for science education research into the processes1 of learning and the interactions of the learners with the sources of information generated by the project, which could contribute to knowledge of informal processes of learning.

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COMMUNICATION ON A PROBLEM SOLVING TASK IN COOPERATIVE LEARNING GROUPS.

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RESEARCH NOTE

This research note reports preliminary findings on the development of communication amongst students working in cooperative learning groups on repeated attempts at a problem solving task. The research is part of a larger study to examine the effects of various strategies for managing student communication which is currently being conducted with Year 8 classes in six Melbourne government schools.

Data on the communication in the group were obtained by recording, transcribing and coding students' conversations whilst they undertook a problem solving activity (Gott & Murphy, 1987). The coded results for one problem solving session for one group (Table 1) show high levels of student interaction. The task related conversations indicated that exchanges about various aspects of the task were in ratio of approximately:

procedures descriptions/explanations reconceptions and reformulations

4 : 2 : 1

The data confirm that although the greatest concerns were for setting up and making measurements, there was significant discussion about information obtained by way of data collected and to a lesser extent how to relate the data to the broader problems posed within the investigation.

Kempa and Ayob (1991) concluded that the group work interaction rarely rose above the level of a factual information exchange about procedures. This suggests that problem solving did not really take place as a group activity. However their observations may reflect their one-shot design.

Our observations of classes and problem solving sessions conducted over an eight week period show a shift towards higher level exchange over that period. The Cooperative Learning Model of Slavin (1983) which proposed four levels of skills may explain this development.

1. Group establishment skills
2. Maintaining a functioning group
3. Skills of reflection and reasoning to formulate understanding at a deep level
4. Reconceptualising skills to stimulate reformulating understanding through new investigations and to communicate the rationale behind the conclusions.

TABLE 1
CODED SUMMARY OF STUDENT CONVERSATION (after Cooper 1982)

	Procedures %	Descriptions & Explanations %	Reconception & Reformulation %
Statements			
Attention focussing	2		
Offers of Assistance	3	8	7
Requests for Action	19	1	
Requests for Information			1
Requests for Help	1		
Other Relevant Comments		1	
Questions			
Requests for Information	8	3	2
Requests for Help	1	1	0
Responses			
Complete Specific Response	16	14	5
Incomplete Answer			
Answers with a Question	1	2	2
Counter-assertion			
TOTAL	52	30	16

In our longitudinal study the social-emotional needs of the group interacted with the completion of the problem solving survival task. The high level of information flow in setting up and completing the task consolidated behaviour at the first two skills levels. In early observations it appears that rather than threaten the positive social-emotional climate of the group, female students in particular, often chose not to argue for their particular beliefs, even when invited by the authors. Students appeared to be struggling to balance Slavin's skill level 3 with the needs of skill level 2.

Later, when the same group undertook the same task for the third time, the group redesigned the investigation in an attempt to reach a satisfactory solution. This time the group sought to deal with all possibilities. The group appeared to be moving towards Slavin's fourth level of skills required for functioning cooperative learning groups.

Teachers involved in the trials in the last two years have suggested that intra-group relations and styles of leadership in the groups are crucial factors in their operation. Preliminary observations would support Gayford's (1992) suggestion that there are potentially important identifiable patterns of group planning and implementation.

Summary

There is some evidence from this study that reflectivity within cooperative learning groups develops over time. Preliminary observations suggest that Slavin's third and fourth levels of skills, those of reflection and reasoning and reconception and reformulation and Kempa and Ayob's higher levels of explanation and insight appear more advanced in groups strategically managed by teachers for such outcomes. Later analyses will permit more detailed accounts of the relationships between the teacher's management strategies, and reflection within groups of different gender composition.

REFERENCES

Cooper, C. (1982) Peer learning in the classroom: tracing developmental patterns and consequence of children's spontaneous interactions. In L. Wilkinson (ed) Communication in the classroom, New York: Academic Press.

Gayford, C. (1992) Patterns of group behaviour in open-ended problem solving in science classes of 15 year old students in England International Journal of Science Education 14 (1) 41-49.

Gott, R. & Murphy, P. (1987) Assessing investigations at 13 and 15. APU Science Survey, London: Department of Education and Science.

Kempa R. & Ayob A. (1991) Learning interactions in group work in science International Journal of Science Education 13 (3) 341-354.

Slavin, R. (1983) When does cooperative learning increase student achievement? Psychological Bulletin 94 (3) 429-445.

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